Journal of Advanced Zoology

ISSN: 0253-7214

*Volume **36** Issue **1** Year **2015** Page **15-25***

Impact of Water Quality on Fish Growth: A Study on Catla catla, Labeo rohita, and Cirrhinus mrigala in Andhra Pradesh and Telangana

Dr. Babu Rao Gundi[1*]

[1*]*Head, Dept of Zoology, NB.Science College and PG.Centre, Charkaman, Hyderabad, 500002,*
Email I'd: dr.g.baburao786@gmail.com

Corresponding Author: Dr. Babu Rao Gundi
[*]*Head, Dept of Zoology, NB.Science College and PG.Centre, Charkaman, Hyderabad, 500002,*

Abstract

Water quality influences the fish's growth, which is vital in Andhra Pradesh and Telangana, to some extent in other places where fishes like *Catla catla, Labeo rohita, Cirrhinus mrigala*, etc., are raised. The review analyzes the effects of temperature, dissolved oxygen, pH, ammonia, and turbidity on the growth performance of these species in the region. Information obtained on various aquaculture farms within the two states shows that variability in water quality is rather large and that it impacts on growth, health, and yield of the fish. The results of the study support the fact that water condition is a critical factor in maintaining and enhancing profitable aquaculture and provide specific guidelines for water quality control to enhance the production of aquaculture farms. Furthermore, the article discusses local factors such as irregularities in monitoring and poor farmer information and underlines the presence of a requirement to apply interventions to boost water quality management locally.

KEYWORDS: Water quality, aquaculture, sustainability, monitoring systems, bioremediation

Introduction

Aquaculture has risen as one of the important sectors in India since it can support food security, poverty relief, and economic development. Of this production, freshwater aquaculture forms a significant proportion of species like *Catla catla* (Catla), *Labeo rohita* (Rohu), and *Cirrhinus mrigala* (Mrigal). These fishes are together known as the Indian major Carps share the most commonly cultured freshwater fish species in India (DAM & INDIA, 2004). They are fast-growing fish species they can grow well in different environmental conditions and they are market-hard assets for both commercial and small-scale aquaculture farmers. Contribution to the improvement of the standard of living of millions of rural households has been realized through aquaculture, especially in states such as Andhra Pradesh, West Bengal, and Telangana where fish farming is a dominant activity. Through policy support, subsidies, and schemes, the Indian government has supported the beginning of aquaculture to increase fish production for exportation making it an important component of India's economy (Bostock et al., 2010). Nonetheless, there is still much to be achieved in the way of sustainable aquaculture practices and optimization of fish resources. Of all the factors that determine the success of aquaculture, water quality where fish are reared plays a significant role (Boyd and Zimmermann, 2000). Infections in water-borne diseases lower growth rates, and increase disease incidences and mortality rates

which are all determinants of the growth of fish farms (McGann et al., 2009). It is against this backdrop that the present study seeks to investigate the correlation between water quality and fish health to improve the sustainability of aquaculture farming systems in India.

It is known that the quality of water affects the development and existence of the organisms in water systems especially in aquaculture. Some of the physical parameters include temperature, dissolved and suspended solids, while the chemical parameters include pH, dissolved oxygen, biochemical oxygen demand, and chemical oxygen demand, and the biological parameters include bacterial load. The primary physical qualities include temperature and suspended solids while the chemical qualities include Dissolved Oxygen (DO), pH, ammonia, nitrates, and CO_2 (Ozbay et al., 2014). Similarly, the biological characteristics concerning the presence of diseases, algae, and plankton are also important in the stock of fish.

Temperature is one of the most effective factors that operate to noncontrolling the metabolic rates of fish. It is to be noted that fish belong to the coldblooded animals and the needs of their growth depend on the temperature of the water (Soares, 2012). In *Catla catla, Labeo rohita,* and *Cirrhinus mrigala*, the temperature for growth is most often between 24-30°C. When the temperature is below or above this range, the growth is slower, stress starts to develop and diseases become more likely (Jana and Sarkar, 2005).DO is another paramount factor that needs to be controlled in the reactor system, factors, and effects of control. Adequate DO levels are essential for the respiration of fish and the breakdown of organic matter in the water. Low DO levels cause hypoxic conditions and adverse effects on fish growth and are likely to cause mortality, particularly in intensive fish production systems (Tucker et al., 2008). Just as the acidity and alkalinity are related to many body functions also affect the availability and uptake rate of nutrients and anabolic reactions. Fish species are said to be more sensitive to abrupt changes in the pH and the differences can cause poor health and slow growth among the fish (Bricker et al., 2012). The other parameters are ammonia and nitrate since ammonia is produced by fish excretion and decomposition of organic matter while nitrate is a breakdown product of organic compounds. Certain concentrations, especially ammonia, are directly toxic to fish, for they affect the gills, inhibit the uptake of oxygen, and in general affect the health of the fish. The physical conditions of water must therefore be well controlled to achieve a balance of the parameters of water quality that are essential in the growth of the fish. In the culture systems of fish in Andhra Pradesh and Telangana, issues affecting water quality are further exacerbated by environmental factors which include agrochemical leaching, industrial effluents, and poor waste disposal. These elements lead to water pollution which in turn leads to challenges in the appropriate rearing of farmed fish. Solving these water quality problems is central to enhancing the productivity and the inability of the aquaculture sector in India. The main purpose of the review is to focus on the effect of water quality on the growth of *Catla catla, Labeo rohita,* and *Cirrhinus mrigala* in the states of Andhra Pradesh and Telangana. These two states are part of the leading aquaculture states in India and the two face unique issues concerning water quality (Ritvo et al., 2000). By reviewing, the article seeks to achieve the following objectives to determine the physical, chemical, and biological parameters of water that had a distant influence on the growth of the three fish species in these areas. The knowledge of how changes in water quality affect growth, health status and diseases in fish under aquaculture is crucial.

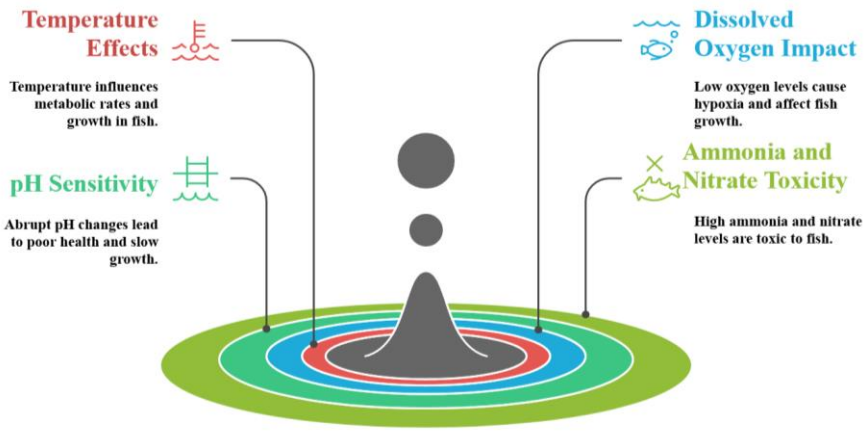

Figure 1: Water Quality Impact on Aquaculture

Preliminary information about the fish species studied

Catla catla (Catla)

Catla catla or simply catla is one of the most popular fish species in Indian freshwater aquaculture. It is characterized by its high growth rate and its large size, which gives it an economic importance. Catla, in particular, is well adapted for polyculture for it feeds on plankton while the other carps are omnivorous (Leal et al., 2010). One major characteristic of the species is that it is very much affected by changes in the environment especially water quality which determines its life and growth. High market demand, especially in India, makes it quite relevant in aquaculture according to Jana and Sarkar. (2005). Therefore, efficient control of catla is crucial to maximizing production in aquaculture systems, especially in Andhra pradesh and Telangana.

Labeo rohita (Rohu)

Rohita or Labeo rohita is one more important fish species in the fresh culture mainly in India. Rohu mostly found in rivers and ponds. It can reproduce very fast. Rohu feeds on both plant materials and debris and makes it suitable for an integrated aquaculture system. According to McGann et al. (2009), the species has a significant role in the polyculture that is used to improve the balance of the aquatic systems by feeding on all the possible foods (Pretty, 2008). This makes rohu an essential fish in Indian aquaculture and plays a great role in food security and economic uplift.

Cirrhinus mrigala (Mrigal)

Mrigal or Cirrhinus mrigala is another species of Indian origin that's widely used in the culture industry in Andhra pradesh and Telangana because of its flexibility in feeding and growing patterns makes pond bottoms clean by consuming organic matter at the bottom of the pond (Jindal et al., 2014). Mrigal is usually grown together with Catla Catla and Labeo rohita in the polyculture system where it has the important role of recycling feed and water quality. It makes the species adaptable to all weather factors a plus to the sustainability of the aquaculture farms. Besides, because is a small fish, Mrigal is suitable to be grown in confined spaces and is suitable for intensive farming systems.

Importance of these species in Aquaculture

Catla catla, Labeo rohita, and Cirrhinus mrigala form the core of India's freshwater aquaculture industry. These species are highly valued because they grow fast, the compatible, and can easily adapt to polyculture systems a very important role in food security, opportunities for income generation, as well as stimulating economic development. In addition, they help maintain ecological balance in the farming zones of aquaculture since they feed in different manners. Being highly valued all over the world fish will continue to be focal to the advancement of sustainable and profitable aquaculture in India.

Table 1: Overview of Major Indian Freshwater Fish Species and Their Role in Aquaculture

Fish Species	Key Characteristics	Feeding Behavior	Role in Aquaculture	References
Catla catla (Catla)	High growth rate, large size, sensitive to water quality	Feeds on plankton	Significant in polyculture systems, high market demand in India, crucial for maximizing production	(Tucker et al., 2008)
Labeo rohita (Rohu)	Native to tropical seas, fast reproduction under proper conditions	Feeds on plant materials and debris	Improves balance in aquatic systems, essential for integrated aquaculture, contributes to food security and economy	(De Silva et al., 2008)
Cirrhinus mrigala (Mrigal)	Flexible in feeding, cleans pond bottoms by consuming organic matter	Feeds on organic matter at pond bottoms	Enhances water quality, suitable for intensive farming, key in recycling nutrients in aquaculture	(Jana and Sarkar, 2005)

Water Quality Parameters That Inhibit Fish Growth

Physical Parameters: Temperature and Turbidity

Temperature is probably one of the most important physical factors affecting the metabolic rates and growth of fish. Fish are ectothermic and the growth of fish depends on water temperature Every type of fish has their specific growth temperature therefore, any change from the said range can cause stress and poor results. The same turbidity interferes with light penetration to promote primary production and has negative impacts on fish since it hinders the functioning of gills. Turbidity also affects the rate of oxygen changes anus exploring the growth and the way fish survives in the water.

Chemical Parameters: pH and Dissolved Oxygen

Ph and level of water affect growth in this sense because metabolic activities and available nutrients affect the growth processes of fish. Most of the freshwater fish such as Catla catla and Labeo rohita prefer water with a slightly alkaline nature (Verdegem, 2013). Large variations in the pH can act as a stress factor in fish, leading to immunosuppression, and lower growth performance. The other parameter, dissolved oxygen is equally important because it is used for fish to breathe and for the oxidation of organic material in water. This means that an organism with a low DO level will have stunted growth and diseases will be easily inflicted on the organism.

Chemical Parameters: Ammonia, nitrates and nitrites

Ammonia, nitrates, and nitrites are nitrogen compounds that are found in aquaculture systems because of the excretion by fish and the decomposition of organic matter. High ammonium concentrations are lethal to freshwater fish and cause gill damage and respiratory stress. Nitrates and nitrites which are less toxic can however build up in water over a period worsening the quality of water and the diseases associated with it. These compounds should be closely monitored or well-filtered to maintain the best suitable environment and health status of the farmed fish (Yusoff et al., 2011).

Chemical Parameters: Salinity

In general, salinity refers to the level of dissolved salts in the water and is an essential factor influencing the welfare of fish. The pH should be slightly alkaline to neutral for fish such as Catla Catla and Labeo rohita because the two species are not suitable for salinity water. A majority of the freshwater species of India are not tolerant to salinity, however, slight variations in salinity levels enhance immunological status at times (Yen, 2009). Nonetheless, a long time of exposure to non-optimal salinity affects fish growth, causes stress, and decreases disease resistance which is not desirable for aquaculture.

Biological Parameters: Algae and Pathogens

Algae growth in the aquaculture systems can be an advantage and disadvantage depending on factors. Algae help the aquatic food chain by providing oxygen as well as food for herbivorous fish. However, intense accumulation of algae, especially in eutrophic conditions may cause oxygen depletion and the liberation of toxins that are damaging to the fish stock and their growth. Aquaculture pathogens which include bacteria, viruses, and parasites are one of the biggest challenges of aquaculture systems. High organic loads, low dissolved oxygen levels, and turbidity make water bodies favorable for the growth of disease-causing pathogens that affect fish production (Zhang et al., 2011)

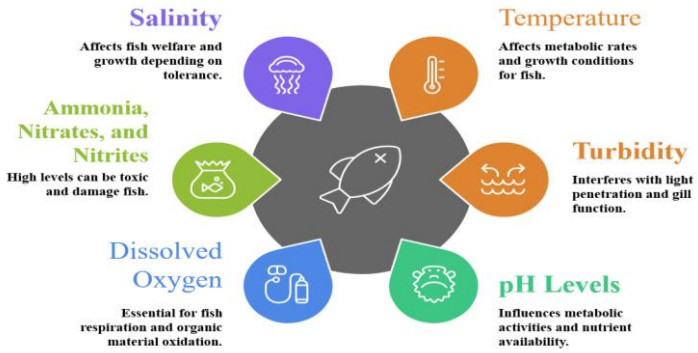

Figure 2: Water Quality Parameters Affecting Fish Growth

Impact of Water Pollutants on the Growth of Fish

Growth Rate and Feed Conversion ratio

It has been observed that water quality is strongly related to the growth rate and feed conversion ratio (FCR) in fish. At the most favorable conditions, including stable temperature, high dissolved oxygen, and low contaminants, the algal growth rates are high (Sindilariu et al., 2009). Water quality, such as high ammonia or low oxygen, causes stomach upsets and decreases the FCR and growth rate. Several researchers have explained that managing the parameters of water quality results in a significant improvement in the fish stock and feed conversion ratio. It is therefore important that proper water management is achieved to increase the productivity of aquaculture and decrease feed costs.

Autoimmunity and Disease Permeability

The article also reveals that water quality has a close relationship with the immune system and disease resistance in fish. Ammonia, low dissolved oxygen or high-water turbidity affect the immune system of fish and hence make them vulnerable to diseases. In highly stressful conditions, diseases such as bacterial infections cause mortality and reduce production in aquaculture (Auffret et al., 2013). It has been established that fish subjects that are placed in good water environments have better immune systems than those that are in bad water environments. Therefore, it is important to control water quality to prevent diseases from affecting the fish.

Behavioral Changes in Fish

Water quality influences both the growth and the immune system of fish and their behavior. Reduced water dissolved oxygen, high ammonia levels, and variations of pH affect the fish in ways like erratic swimming, reduced feeding, and surface gulping (Dias et al., 2011). Such behaviors reveal stress and have the potential to reduce fish growth rates. Stress resulting from unfavorable water conditions is also chronic and results in changes in reproductive behavior and activity (Murthy et al., 2010). Hence, the study of water quality and fish behavior is crucial to achieving the best fish welfare and performance in aquaculture.

Table 2: Impact of Water Quality Parameters on Fish Growth, Health, and Behavior in Aquaculture

Parameter	Impact on Growth Rate	Impact on FCR	Impact on Immune System	Disease Vulnerability	Behavioral Changes	References
Stable Temperature	High growth rate	Improved FCR	Strengthens immune system	Reduces disease vulnerability	Normal swimming and feeding behavior	(Dias et al., 2011)
High Dissolved Oxygen	Promotes optimal growth	Improved FCR	Enhances immunity	Low disease risk	Normal behavior	(Mandal et al., 2013)
Low Dissolved Oxygen	Reduces growth	Poor FCR	Weakens immune system	High vulnerability to bacterial infections	Surface gulping, erratic swimming	(Bostock et al., 2010)
High Ammonia	Decreases growth	Poor FCR	Weakens immune response	Increases vulnerability to infections	Erratic swimming reduces feeding	(Sogbesan and Ugwumba, 2008)
Low Ammonia	Supports normal growth	Maintains optimal FCR	Supports immune function	Reduces risk of diseases	Normal feeding behavior	(Yusoff et al., 2011)
High Turbidity	Impedes growth	Poor FCR	Weakens immunity	High susceptibility to diseases	Erratic behavior, stress	(McGann et al., 2009)
Low Turbidity	Promotes growth	Supports optimal FCR	Strengthens immunity	Low disease vulnerability	Normal behavior	(Boyd and Tucker, 2012)

pH Variations	Reduces growth	Poor FCR	Causes stress on the immune system	Increases disease susceptibility	Erratic swimming and reproductive changes	(Bostock et al., 2010)
Good Water Management	Maximizes growth	Improves FCR	Strengthens immunity	Minimizes disease risk	Ensures normal fish behavior	(Yen, 2009)

Regional Perspective: Andhra Pradesh and Telangana

Summary of Aquatic Environments in the Areas

Andhra Pradesh and Telangana are two states in the southern part of India and contain a variety of water bodies like rivers, lakes, reservoirs, and seas. These ecosystems include Godavari, Krishna, and Musi rivers acting as sources of fresh water for irrigation, human consumption, and fish farming. They also have large aquaculture production, particularly in freshwater farming although many of them have both marine and freshwater segments. More specifically, Andhra Pradesh is a leading state that has many commercial aquaculture farms for freshwater fish farming. The hydrological health of such water bodies and streams is important for fish stock and for promoting fish farming.

Water Quality Challenges in Andhra Pradesh

Water quality issues are very pronounced in Andhra Pradesh, especially in the freshwater resources and rivers. The increasing growth of aquaculture, together with industrial effluent discharges has caused high concentrations of ammonia, and suspended solids (Munilkumar and Nandeesha, 2007). This has led to lowered dissolved oxygen levels which are important in fish well-being development. Nutrient overloads from agricultural runoff and aquaculture waste and eutrophication in freshwater bodies make it even worse (Simbeye and Yang, 2014). These water quality factors reduce fish production and cause farmers to pay more for water management.

Water Quality Challenges in Telangana

The case with Andhra Pradesh, the quality of water in Telangana is affected by the processes of urbanization and agricultural development. Hyderabad's Musi River has suffered from water pollution by industrial effluents and untreated sewage (Sipauaba and Boyd, 2003) Additionally, increased exploitation of groundwater for irrigation has affected the chemistry of water in some regions increased salinity, and dissolved oxygen. The above water quality challenges affect fish health and growth, (Kocer and Sevgili, 2014). It was also found that the sustainability of water management is one of the significant issues that the aquaculture sector of the region has to face in the future.

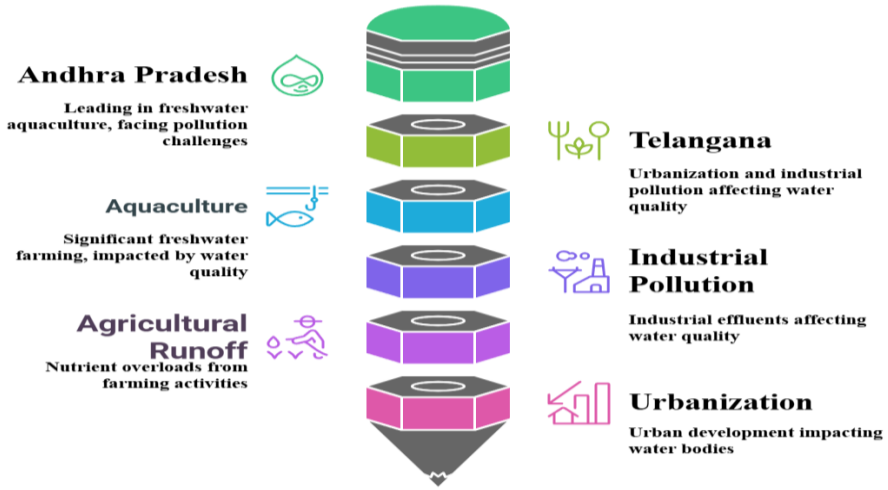

Figure 3: Aquatic Ecosystems and Challenges in Andhra Pradesh and Telangana

Case Studies and Data Review

Studies Conducted on Water Quality in Andhra Pradesh

Several researchers have examined the water quality in Andhra Pradesh, with most research concentrating on aquaculture systems. The relationship between water qualities such as ammonia, pH, and dissolved oxygen with the growth of fish in the state's aquaculture farms. The study established that water quality affected fish health and productivity, and poor oxygen levels reduced growth rates and increased mortality (Yusoff et al., 2011). It also pointed out the need for frequent water quality testing or the needs of *Catla Catla* and *Labeo rohita.*

Studies Conducted on Water Quality in Telangana

In Telangana, some researchers have conducted research on the impacts of industrial pollutants on water quality and impact on fish production. The Musi River which receives most of the industrial effluents realized that the chemical content had a direct impact on fish. There were increased levels of ammonia and nitrates that led to slow growth of the fish and bad feed conversion ratios. It also identified that the effects of salinity and water temperature variation in the area led to stunted growth and low fish yield in affected zones.

Comparative Analysis of Findings

A comparison of the findings of the studies carried out in Andhra Pradesh and Telangana shows that while water quality issues are similar, there are some differences by region. Both states suffer from eutrophication, caused by nutrient overloads from agricultural sources and aquaculture wastes (Subasinghe et al., 2003). But Andhra Pradesh's aquaculture systems are in a better position to control the quality of water as they practice proper management and have easy access to better filtration technologies (Belton et al., 2014). While Andhra Pradesh's problems are amplified by a high population density, Telangana faces even higher industrial pollution as well as highly unpredictable rainfall patterns, which greatly hinder water quality control and fish development.

Table 3: Comparative Case Studies on Water Quality and Its Impact on Aquaculture in Andhra Pradesh and Telangana

Region	Key Water Quality Issues	Main Pollutants	Impact on Fish Growth	Major Fish Species Affected	References
Andhra Pradesh	Poor dissolved oxygen	Ammonia, low pH	Reduced growth, increased mortality	*Catla catla, Labeo rohita*	(Seshagiri et al., 2013)
Telangana	Industrial pollutants, salinity, and temperature variation	Ammonia, nitrates, heavy metals	Stunted growth, reduced productivity	*Labeo rohita*, *Cirrhinus mrigala*	(Jana and Sarkar, 2005)
Andhra Pradesh	Eutrophication	Phosphates, nitrates	Decreased oxygen, fish kills	*Catla catla*, *Labeo rohita*	(Tucker et al., 2008)
Telangana	Industrial Pollution	Heavy metals, ammonia	Poor growth and higher mortality	*Labeo rohita*, *Cirrhinus mrigala*	(Jana and Sarkar, 2005)
Andhra Pradesh	Filtration Technologies	Advanced filtration systems	Improved growth and productivity	*Catla catla*, *Labeo rohita*	(Yen, 2009)

Challenges and Knowledge Gaps

Inconsistent Monitoring of Water Quality

A common problem in aquaculture water quality management is irregular monitoring of water quality parameters (Good et al., 2009). It also noted that most aquaculture producers fail to sample their water with the required frequency and accuracy thus missing changes in important parameters such as pH, ammonia, and dissolved oxygen. Incorrect and improper monitoring of the environmental parameters can lead to fish stress,

diseases, and stunted growth. Also, inadequate sampling methods and restricted availability of live information are other factors in this issue. In their study, McGann et al. (2009) pointed out that a combination of a sampling regime and a comprehensive monitoring system can greatly enhance water quality management in aquaculture systems.

Lack of Awareness Among Farmers

Most of the aquaculture farmers are not well informed on the aspect of water quality and the health of the fish that they rear for sale. According to Bostock et al. (2010), farmers are less aware of water factors including nitrogen, salinity, and temperature with enormous impacts on fish health. No training programs or extension services are available in rural areas, which makes this problem worse. Beddington. (2010) found out that when farmers are informed of the consequences of poor water quality, they are likely to improve their usage of water hence increasing the productivity of aquaculture and sustainability. The farmers are also ignorant of water pollution and its impacts whether in small-scale farming or commercial farming.

Need for Region-Specific Studies

The call for regional studies is therefore very important in tackling the water quality issues that are related to aquaculture. According to Seshagiri et al. (2013), the water quality standards are different because climate, water source, and farming practices differ from one area to another. Thus, water quality in aquaculture systems in Andhra Pradesh may be different from that in Telangana because of differences in rainfall and levels of industrial pollution. As a result, it is required to carry out regional investigations that would consider these geographical distinctions to design improved and specific water quality management measures (Colt, 2006). It is also possible to pinpoint certain pollutants which are characteristic of the region.

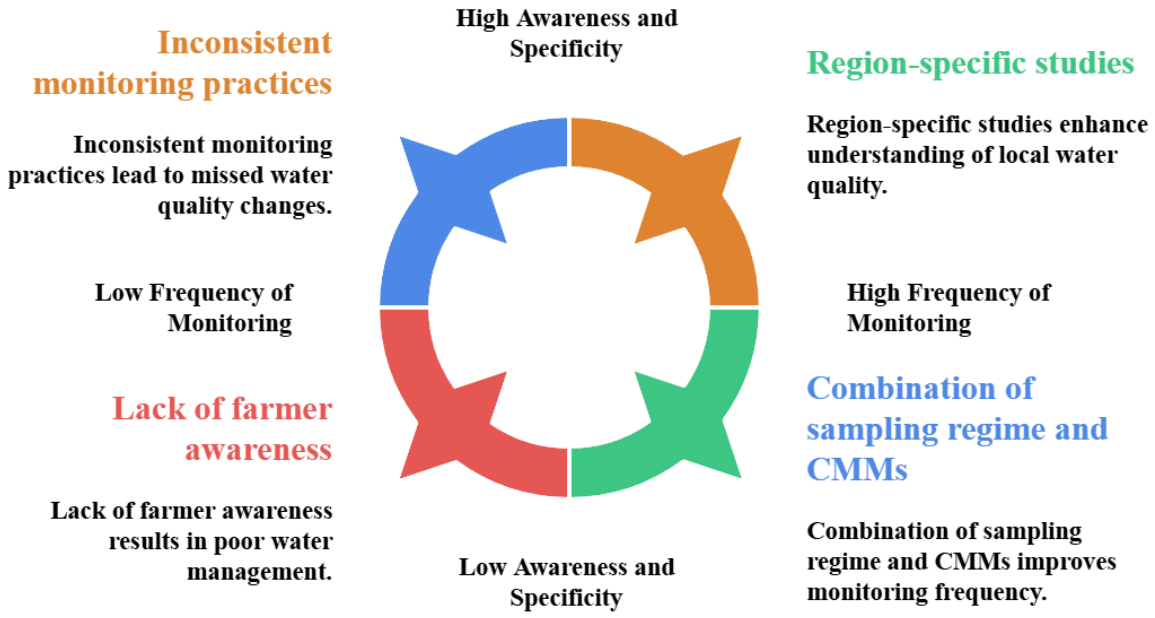

Figure 4: Prioritizing Aquaculture Water Quality Challenges

Recommendations and Future Directions

Strategies for Improving Water Quality

A priority need in improving water quality in aquaculture systems should be the incorporation of advanced filtration as well as bioremediation practices (Boyd & Tucker, 2012). The use of biofilters and aeration systems will go a longy in improving water oxygenation and nutrient cycling (Murthy et al., 2010). The possibility of using algae biofilters to control nitrogen and phosphorus concentrations. Hence, while using these strategies, regular water quality tests guarantee that fish achieve the best health state. Applying these methods will enhance the sustainability of aquaculture practices about the impacts on the environment and the growth rate of fish as well as the productivity of the system.

Policy Interventions and Farmer Training Programs

It is found that policy interventions and farmer education have significant roles to play in the better management of water quality in aquaculture. Bostock et al. (2010) opine that the authorities involved in providing water should set higher standards of water quality and facilitate the farmers with necessary incentives for sustainably using water A series of farmer training that aims to adequate knowledge and understanding of water quality monitoring and how best to manage water parameters will ensure that there is adequate awareness and output is increased (Barnard, 2004). Moreover, there is a need to increase awareness to bring positive change in the case of overfeeding, generators, waste, and pesticide use among others. Local and national education is important in changing the attitude of the aquaculture sector towards water quality at large.

Research Opportunities in the Field

Research in the area of water quality management is becoming increasingly important and there is a need for more investigation in the field especially in terms of new technologies and regional issues. It argues that more studies should be done about the region in question to establish the specific water quality challenges in various systems of aquaculture. Studies have underlined the importance of the new technologies for filtration as well as the recycling systems and the introduction of environmentally friendly chemical agents for water treatment as the major ways to enhance sustainability. Furthermore, the examination of the relationships between fish species and water quality parameters could enhance the development of better approaches to managing aquaculture production environments.

Conclusion

The quality of water affects the growth and overall health of fish that are reared in these systems of aquaculture. Manipulation of the key water quality indices which include dissolved oxygen, pH, temperature, and nutrients affects fish production rates, feed conversion ratio, and the overall system performance. Effective water monitoring standards, constant filtration processes, and few adopted bioremediation outcomes are promising signs of improved water quality and detrimental hindrances to the environment. However, some of the challenges such as erratic monitoring, lack of awareness among farmers, and specific region constraints still act as constraints to attaining the best quality water in all the systems of aquaculture. In the future, there is a great prospect for advancements in the management of water quality. The future of aquaculture is the integrated systems that comprise efficient techniques like real-time monitoring systems, advanced methods of filtration, and nutrient balance production systems. However, it will be necessary to stress that increased use of environmentally friendly technologies will play a significant role in making aquaculture as harmless for the environment as possible. Within the next years, there is a need to increase the level of research, technological development, and farmer training to fill existing gaps and enhance systems of water management. When taking into consideration the fact that aquaculture is rapidly developing as a means to feed the growing world population, safe management of water will remain a critical factor in the sustainability of the sector. The future will require multi-disciplinary stakeholder engagements from researchers, policymakers, and farmers to define and develop a future where the aquaculture industry will not only be sustainable but will not have negative impacts on water resources and the ecosystem.

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