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Preventive Strategies and Health Management Framework for Controlling Fish Diseases in Aquaculture: Review Paper

Khalid Rehman
Department of Zoology, Kohat University of Science & Technology, Pakistan
Email: khalidrehmanzoologist@gmail.com
Istiraj
Department of Zoology, Islamia College, Peshawar, Pakistan
Fardous Jamal
Department of Zoology, Kohat University of Science & Technology, Kohat, Pakistan
Raheela Noor Memon
Assistant Professor Zoology, Govt Girls Zubaida College, Hyderabad, Sind, Pakistan
Musawair Ahmad
Department of Zoology, Kohat University of Science & Technology, Kohat, Pakistan
Faiza Shahid
Department of Zoology, Kohat University of Science & Technology, Kohat, Pakistan

Author Details

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Corresponding E-mail & Author*:
Khalid Rehman
Department of Zoology, Kohat University of Science & Technology, Pakistan
Email:khalidrehmanzoologist@gmail.com

Abstract

Aquaculture has become one of the most rapidly expanding food production industries of the planet, but its sustainability is rapidly diminishing due to the popularity of infectious diseases that lead to substantial financial losses and deterioration of fish welfare. The management of diseases in aquaculture will require transition to preventive treatment of diseases through an integrated health management system rather than reactive treatment. The present review summarizes the existing evidence in the area of preventive measures, such as biosecurity, water quality control, vaccination, the use of immunostimulants, pro- & prebiotics, and dietary interventions, the use of early disease detection techniques. The framework focuses on the use of a holistic approach through the integration of environmental management, host resistance enhancement, and pathogen control to minimize outbreaks of diseases. Besides, the paper emphasizes the significance of the ecosystem-based management, training of farmers, and policy-level intervention to reinforce the measures of the disease control. Issues like antibiotic resistance, the effects of climate changes, and inaccessibility to vaccines in the developing world are also addressed. Through the description of strengths and weakness of current approaches, the review offers a holistic basis of designing sustainable, preventive and adaptive health management models within aquaculture. The results support the importance of using multidisciplinary efforts to achieve fish health, food security, and sustainability of the aquaculture industry

Introduction

Introduction to Aquaculture and its Challenges

Aquaculture is becoming an increasingly important component of the global food supply. With world populations continuing to rise, a greater number of people rely on fish and other seafood products as their primary sources of protein. Globally, seafood represents 17% of all animal protein consumed, and the rate of seafood consumption has, on average, increased 3.0% per year from 1961 to 2020, and global fish demand is expected to double by 2050 (Naylor, Kishore, et al., 2021). The demand for seafood is met by two industries: wild-caught fisheries and aquaculture. Within the last 30 years, seafood production using aquaculture has steadily increased by roughly 4.5% annually and now produces more than half of all seafood consumed in the world (Department, 2018).

Aquaculture production of fish makes up forty-four percent of total fish production in 2014 which is 74 million tons of fish worth of 160 billion dollars. Almost all fish produced from aquaculture is for human consumption (Assefa & Abunna, 2018).

Huge loss of production in aquaculture is occurring because of many reasons. Among these causes, a disease is the most serious constraint that causes damage to the livelihood of farmers, loss of job, reduced incomes, and food insecurity. Studies showed that almost fifty percent of production loss is because of diseases which are more severe in developing countries. This is because ninety percent of the aquaculture firm is in the developing world. The annual loss of revenues because of disease reaches up to 6 billion dollars. For instance, in Chile, infectious salmon anemia alone costs 2 billion dollars and caused 20000 workers to lose their jobs. In China, one of the leading countries in aquaculture production has a loss of 15 percent of the total fish production to diseases (Gopinath, Madhav, Krishnan, Malolan, & Rangarajan, 2020).

Cause of Diseases in Fishes

Due to water pollution.
Acidic or alkaline water.
Decrease or increase in water temperature.
Harvesting more fish seed.
Due to the high amount of substances like zinc, mercury, copper, cadmium etc. in the water, they get deposited on the body of the fish and which makes a wound on the head.
Unbalanced fish diet.

Some Important Signs of Disease, Infection (Disease) in Fishes

There are signs of different diseases in fish such as loss of appetite, lack of good growth in the body, repeated breathing (gulfing) of fishes coming to the surface of the water, jumping repeatedly on the surface of the water, rubbing against the dam of the pond, slow movement in fishes, fins, gills and skin rot. Small specks of blood appearing on the body of the fish, not eating well, change in color of fish, a sticky fluid that comes out from the surface of the fish body. On the fish body, there is a wound (spot) that is red, white, blue, and black. Loss of physical balance of the fish, fish swimming slowly on the surface of the water in a pond, eyes blurred, Eye rot, and eye protrusion. Belly is bloating (Sen & Mandal, 2018).

Precautions for Disease Management in Fish Farming

Use lime, $KMnO_4$ in the pond from time to time.
Check the environment and pond water quality, then stock the seeds in the pond, otherwise do not do it until it is fine.

Before harvesting the fish, dry the pond and leave it for some time. Due to which the harmful bacteria, fungi, insect moths, unwanted, useless fishes, weeds etc. get eliminated in the pond. After the pond dries up, remove the aquatic weeds, snail etc.
Use certified seed in the pond which is disease free and of good quality.
Do not stock more seeds in the pond.
Give balanced food to the fishes 2-3 times a day.
If we are transferring one-year-old fish from one pond to another, then first treat the fish.
If disease has been found in a pond, then after drying the net and treatment, used in it, it should not be otherwise it should not.
Protect the fish from dog, snake, animal which harms it. Carry the dead diseased fishes somewhere far away on the pond and burn them or bury them in the soil.
Get the sick fish out of the pond and separate it after treatment.
Do not collect fish in the pond which fight with each other.
Send the patient fishes in a polythene bag to the laboratory for examination, if sending live fish, and then send it in a polythene bag with oxygen and water.
When the sky is cloudy, then the fish should not be given supplementary food at that time.
If the color of the water becomes green and the water starts to smell, then the use of dietary supplements should be stopped.
If you see signs of diseases in the fish, immediately contact the fish doctor or fish specialist.

Major Diseases in Fish Farming

Protozoan, fungal, bacterial, viral, crustacean, and helminthes infections, and many others, can affect fish in different ways. Table 1 in this article lists some of these illnesses (Dinesh et al., 2022).

Table: 1. Common Diseases in Aquaculture

#	Disease Condition	Symptoms	Involvement of Pathogens	Treatments
1	Columnaris Disease	Lesions that are hemorrhagic and ulcerative and may appear yellow to orange due to bacterial development and pigmentation on the fins, head, and back.	Flavobacterium columnare (Flexibacter/ Cytophaga columnaris)	• Change water. • Add aquarium salt. Treat with copper sulphate or antibiotic.
2	Tail rot and Fin rot	Erosions, discoloration and disintegration of fins and tails of fishes.	A. hydrophila, Pseudomonas spp., Cytophaga spp., Haemophilus spp.	• Give dip treatment to infected fish with copper sulphate for 1 to 2 min. @ concentration of 2 mg l^{-1}.
3	Swim bladder stress syndrome or Environmental disease	Swim bladder hyperinflation, excessive positive buoyancy, and increased mortality.	Environmental issues.	• Keep an eye on dissolved oxygen (DO). • Avoid algae blooms, maintain the effectiveness of waterlines and pumps, and ensure adequate water exchange.
4	Gas bubble disease	Bubbles can be seen in the stomach, eyes, skin, gills, fins, mouth, swim bladder, digestive	Environmental issues.	• Keep an eye on dissolved oxygen (DO). • Avoid algae blooms,

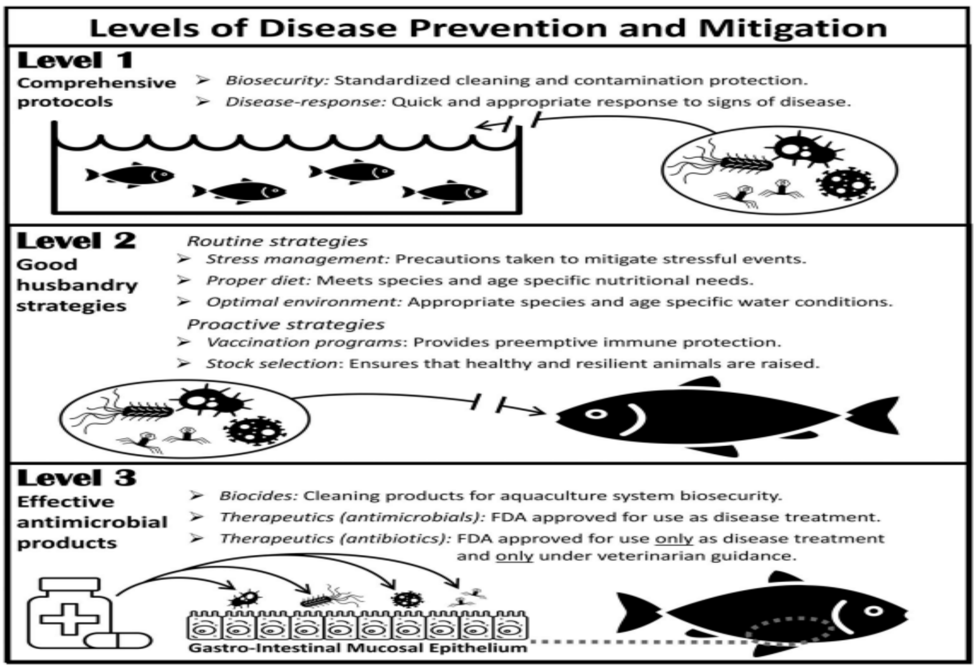
		tract, and exophthalmia in affected fish.		maintain the effectiveness of waterlines and pumps, and ensure adequate water exchange.
5	Aeromoniasis or Motile aeromonas septicaemia	Lesions with haemorrhage and ulceration on the head, the fins, and the exophthalmia.	Aeromonas hydrophila, A. veronii bv. Sobria, A. sobaria	• Avoid over stocking in fish farming.
6.	Edwardsiellosis or Edwardsiella septicaemia	Internal organ, skin, fin, and body ulcerative abscesses as well as rectal protrusion.	Edwardsiella tarda Teramycin	• Water quality management in fish farm. • Reduce stocking density. • Apply oxytetracycline at 55 mg kg-1 fish for 10 days.
7	Eye disease	Cataracts harm the cornea, the eyeball turns red and putrid, eventually the eye becomes damaged and drops.	Aeromonas liquefaciens, Staphylococcus aureus, various other bacteria	• According to their weight in fish food, potash 2-3 ppm. • Teramycin 70-80 mg is given for 10 days. Streptomycin 25 mg kg-1 by weight injected in the fish body.
8	Pseudomoniasis/ Psedomonas septicaemi	Skin, fins, and tail hemorrhages	Pseudomonas sp., Pseudomonas fluorescens	• Avoid over fish stocking. • Maintain water quality.
9	Saprolegniasis	Fish become sluggish, skin bleeds and ulceration, and cotton wool grows on them with grey spots.	Saprolegnia parasitica	• Make a 3% solution of common salt and use it. • It is recommended to apply a bath treatment with NaOH (1025 g L-1 for 10-20 min), KmNO4 (1 g in 100 L of water for 30-90 min), or CuSO4 (5-10 g in 100 L of water for 10-30 min). • If there is a small pond, then using 1 g malachite green at the rate of 5-10 m, water can be beneficial.
10	Branchiomycosis (Gill rot disease)	Fish with melting and decaying gills (redness of gills that later turn greyish-white, necrosis of gill filaments) have trouble breathing as a result, which causes them to reach the surface of the pond and repeatedly open and reopen their mouths in an	Branchiomyces demigrans	•Uses lime at the rate of 50-100 kg ha-1 in the fish pond. • By making a solution of 3-4% salt, the fish affected by the disease are immersed for some time.

		effort to breathe.		• If the pond is deep, use copper sulphate at the rate of 8 kg ha-1 .

Current Approach to Disease Prevention and Mitigation

Maintaining an effective defense system against pathogens is essential for the overall success and sustainability of all types of aquaculture. Currently, the approach to disease prevention and mitigation utilized by US finfish aquaculture can be thought of as having three levels. Each level contributes differently to the overall protection of the animal from pathogens (Figure 1). Comprehensive protocols standardize the methods used by facility personnel to prevent contamination and increase their preparedness for disease events (Schwarz, van Senten, Jahncke, & Lazur, 2019). Protocols are enforced at a facility-wide scale and restrict the potential for pathogens to enter an aquaculture system, disseminate within and contaminate environments outside a facility. Good husbandry strategies refer to animal care within the aquaculture system and support overall fish health. These strategies can reduce stress, enhance the fish immune system, increase disease resistance and effectively function to prevent a pathogen from exploiting the fish and negatively impacting their health. However, if a pathogen is able to evade protocols and enter an aquaculture system, and the fish's natural immune defenses do not eliminate the pathogen, then appropriate antimicrobial products can be used to eliminate the threat and protect fish health (Arechavala-Lopez, Cabrera-Álvarez, Maia, & Saraiva, 2022).

FIGURE: 1. three levels of disease prevention and mitigation. Level 1 represents protocols such as biosecurity and disease response protocols, which function to reduce the likelihood of a pathogen entering an aquaculture system. Level 2 represents good husbandry strategies that function to enhance the ability of the fish immune defenses to prevent disease. Level 3 represents effective antimicrobial products that can be used to kill harmful pathogens, which have evaded the first two levels of defense and manifest in the fish to cause disease or death.



The use of antibiotics is under strict control and regulatory measures because of drug resistance and residue related issues (Elbahnaswy & Elshopakey, 2024). In response to reduced antibiotic use in fish, production vaccines have been playing a key role in infectious disease control in aquaculture for decades. Vaccines get wide acceptance for the fact there is no risk of drug resistance development in vaccinated animals and protection of minority unvaccinated animals because of herd immunity (Dien et al., 2023).

A single approach to prevention and control of aquaculture health is not successful alone. Rather a combination of different strategies is effective. Setting up a national or regional information exchange between farmers and responsible parties is compulsory. Besides applying all these strategies, surveillance for diseases and having sensitive and specific diagnostic tests are invaluable to assure healthy fish. This review has the aim of summarizing some of the best approaches to prevention and control of infectious disease of fish in an aquaculture environment.

The Role of Vaccines in Control and Prevention of Infectious Disease in Aquaculture

Advancing vaccination is one of the most important, and probably the priority, approaches to prevention and control of infectious disease of fish. Treating many of the bacterial infections in aquatic animals using antimicrobials only is impossible (Dadar et al., 2017). There are improvements in fish vaccination recently. Some of the improvements include immunization of large stock at a time and the development of multivalent vaccines (Naylor, Hardy, et al., 2021).

There are few important considerations that should be taken into account before application of vaccination in fish. These considerations include the following points: fish species to be vaccinated, status of the immune system of the fish, production cycle, and life history of the aquaculture system, which diseases need to control in aquaculture, when do these diseases occur (seasonal distribution of diseases in the aquarium), farming technology (handling and mechanization), environment (temperature and salinity), stress factors, nutrition, and cost benefit (Vaseeharan & Jesudhasan, 2024).

The Use of Antibiotics in Aquaculture

Currently, there is a common understanding that antibiotic for protecting fish from disease should remain low (Anokyewaa et al., 2021). Extensive use of antibiotics may result in resistance development. The use of antibiotics in aquaculture is no more primary treatment option. Even though using antibacterial agents in food animal species, including fish, is controlled by regulations, particularly in Europe and the USA, a wide range of medically and veterinary inhibitory compounds are in use in aquaculture (Austin, 2017). Administering antimicrobials in aquaculture is different from administering in terrestrial animals. This difference particularly adding drugs to the water with or without feeds results in environmental disturbance of the microbiota (Menon et al., 2023). Using antibiotics in fisheries routinely in aquaculture that are in use for human medication is a risky act. Aquaculturists are advised to use other prevention approaches rather than antibiotics administering but if the use antibiotics is a must in some circumstances, they have to administer only approved drugs for fish (O'Flynn et al., 2021). The American FDA developed a list of chemicals and antibiotics list for use in aquaculture which has undergone review and is classed as new animal drugs of low regulatory priority. These include compounds such as acetic acid, carbon dioxide gas, hydrogen, sodium chloride, or even garlic (used for control of helminth and sea lice infestations of marine salmonids), onion (used to treat external crustacean parasites), and the ice used to reduce the metabolic rate of fish during transport (Diwan, Harke, Gopalkrishna, & Panche, 2022).

Conclusion

To ensure sustainable fisheries production in the region, it is crucial to gain a comprehensive understanding of disease prevalence, indigenous technologies for disease prevention and control, the formulation of an effective economic biosecurity program, and the execution of best management practices and husbandry measures at the farm level. To protect the fish from illnesses and to avoid the harm they do, the farmer brothers should take certain actions, such as using a net after treatment, regulating the water quality of the fish farm, preventing overfeeding, dumping sick fish in the soil, and so on, before fishing in the pond.

Conflict of Interest Statement The authors declare no conflicts of interest.

Data Availability Statement Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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