# Overview of Fish Bacterial Disease

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## Abstract

The world population is continuously increasing. Due to this, the demand for aquaculture products is also increasing. Aquaculture is one of the most important food-producing sectors that play a significant role in fulfilling the world's food demands. However, with the flourishing fish aquaculture sector, the susceptibility of fish to infectious diseases has increased considerably, due to aquaculture malpractices and other anthropogenic and environmental factors. This can cause huge mortality of farmed fish. Many pathogenic bacterial species have been reported that can cause mass mortality incidents in cultured fish. Fish show morphological, behavioral, and biochemical symptoms and signs in response to these infectious diseases. Prophylactic measures should be taken in fish aquaculture sites to control these infectious diseases. The drugs and chemicals used for the treatment of fish diseases have environmental and human health impacts. Therefore, knowledge regarding their safe use is recommended for fish aquaculture farmers to prevent their adverse effects on the aquatic environment and human health.

Keywords: Aquaculture, Fish, Bacterial diseases, Treatment, Prevention, Human Health, Environmental impacts

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## Introduction

The aquaculture industry has witnessed unprecedented growth over the last few decades, becoming a critical contributor to global food security and economic development. Despite its remarkable advancements, the sector faces a persistent challenge in managing infectious diseases, particularly those caused by bacterial pathogens. Fish bacterial diseases are among the leading causes of morbidity and mortality in aquaculture, accounting for substantial economic losses, reduced fish welfare, and compromised product quality (Bondad-Reantaso et al., 2005).

Bacterial diseases in fish result from complex interactions between the host, pathogen, and environment. Stressful farming conditions, including overcrowding, fluctuating water temperatures, suboptimal water quality, and poor biosecurity measures, exacerbate the susceptibility of fish to infections (Austin & Austin, 2012). Pathogens such as *Vibrio viscosus, Piscirickettsia salmonis, Renibacterium salmoninarum, Vibrio anguillarum* and *Streptococcus iniae* have been extensively reported in aquaculture systems, affecting freshwater, brackish, and marine fish species globally (Noga, 2010).

These bacterial infections can manifest in diverse ways, including external lesions, fin erosion, systemic infections, and even sudden mass mortalities under severe outbreaks (Rigos & Papandroulakis, 2015). In addition to their direct impacts on fish health, bacterial diseases can result in the development of antimicrobial resistance (AMR) due to the overuse of antibiotics in aquaculture, posing a serious threat to public health (Cabello et al., 2013).

Recent advances in disease diagnosis, such as molecular and immunological techniques, have enhanced the detection and characterization of pathogens. Genomic studies have identified some important virulence factors and host-pathogen interactions that can provide a basis for targeted therapeutic and preventive strategies. Vaccination has become one of the major strategies for combating fish bacterial diseases, as well as the development of probiotics, immunostimulants, and other sustainable methods (Sommerset et al., 2005).

The present chapter covers the aspects related to the etiology, epidemiology, pathogenesis, clinical signs, diagnostic techniques, and management strategies adopted against bacterial diseases in fish. The integration of advanced diagnostic techniques with sustainable management practices has been emphasized to build resilience into aquaculture systems with a view to their sustainability over a long period.

### 1. Winter Ulcer Disease in Atlantic Salmon: A Comprehensive Overview

Winter ulcer disease is a major threat to the sector especially in farming of Atlantic salmon among the global species of fish. This disease commonly occurs when the climate is cold, and it has detrimental effects to fish and production. It is characterized by severe skin ulcers affecting mainly the scale-covered part of the body as well as configuration of petechial hemorrhages in inner organs. This results in some economic consequences, though actual reported mortality rates appear few in comparison, since these affected fish dwindled quality for harvest (Ghasemieshkaftaki, M. 2024).

#### i. Causative Agents and Pathogenesis

Winter ulcer disease was first described in the early 1990s in Norway and later in Iceland and Scotland. In the past, many possible causes of winter ulcer disease were suggested, however, bacteriological research has determined that the primary pathogen is the psychrotrophic bacterium *Moritella viscosa* (formerly known as *Vibrio viscosus*) (Ghasemieshkaftaki, M. 2024). A Subsequent study by molecular analysis using 16S rRNA gene sequencing further supported the reclassification of *V. viscosus* to *M. viscosa* (Ghasemieshkaftaki et al., 2024).

However, *M. viscosa* is not the only bacterium associated with winter ulcer infections; *Vibrio wodanis*, a relative of *Vibrio logei*, has also been implicated in winter ulcer infections in Norway, Iceland, and Scotland. Although experimental infections with *M. viscosa* strains produced symptomatic winter ulcers, *V. wodanis* is not pathogenic when inoculated, but may rather be involved in the slowing of the healing of ulcers that were originally caused by *M. viscosa* (Ghasemieshkaftaki, M. 2024).

ii. Symptoms and Diagnosis

The clinical manifestation of winter ulcer disease is characterized by easily observed skin lesions that evolve to form large ulcers with muscle tissue exposure. Other signs that may be observed in infected fish include general body emaciation and lack of strength, loss of appetite and general ill health because the disease is systemic in nature. *M. viscosa* isolation from swabs taken from ulcer sites is the common laboratory diagnosis, in conjunction with biochemical and molecular testing.

iii. Treatment Options

An effective treatment strategy is crucial for managing winter ulcer disease in Atlantic salmon. Prophylaxis is done through vaccination, and an inactivated oil-adjuvanted vaccine against *M. viscosa* has been found to provide adequate protection to the Atlantic salmon. At present, this vaccine is combined with other oil-adjuvanted multiple vaccines that are widely used in the salmon farming industries in Norway, Faroe Islands and Iceland. Surprisingly, although *M. viscosa* is commonly connected with Atlantic salmon, the pathogen has been reported in other fish species including plaice (*Pleuronectes platessa*) and rainbow trout; therefore, it is not strictly a salmonid organism (Furevik et al., 2023).

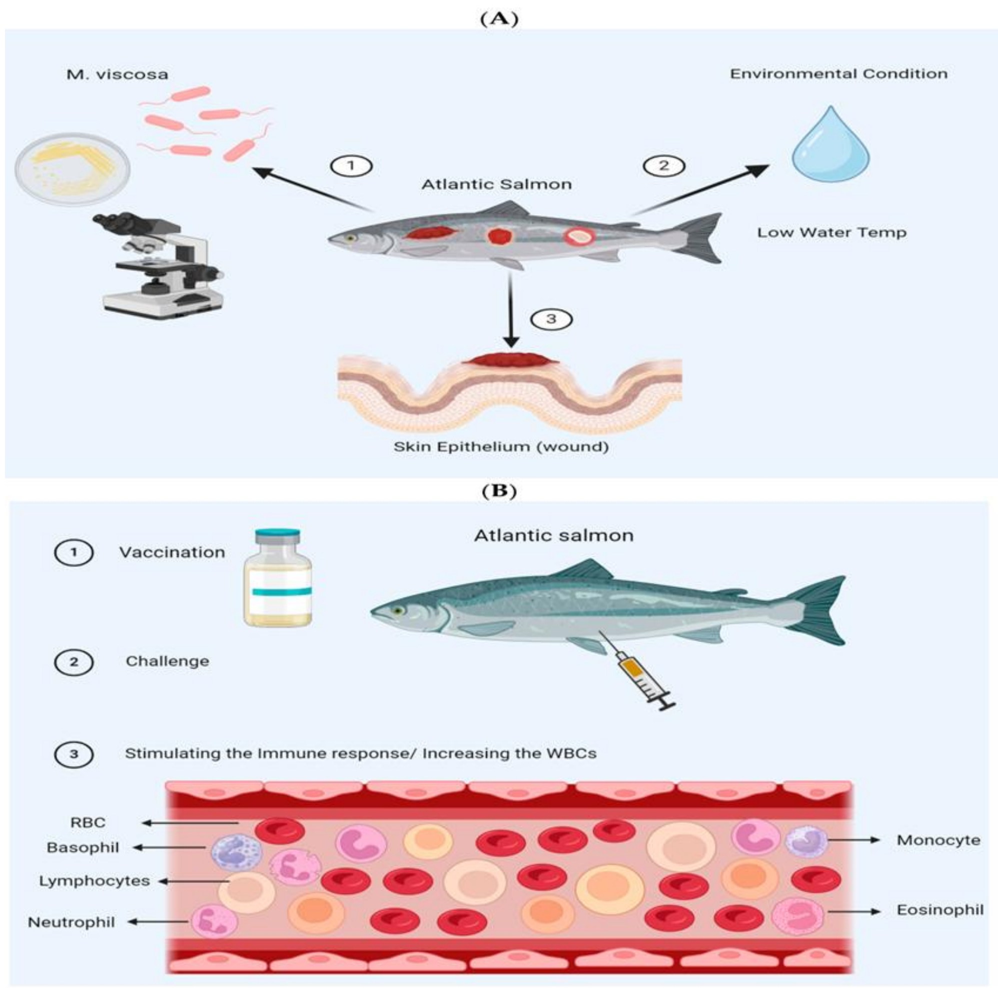


Fig. 1: (A) Mortality and clinical signs reported in Atlantic salmon after challenge with *M. viscosa*. This bacterium can affect Atlantic salmon at lower temperatures. (B) Atlantic salmon were vaccinated and then challenged with *M. viscosa*. A significant increase in WBC levels was observed after the challenge. Increasing levels of lymphocytes and low mortality rates indicated the appropriate functioning of the adaptive immune response in Atlantic salmon immunized with ALPHA JECT micro IV vaccine. This illustration was created by the author using BioRender (https://biorender.com/) (accessed on 17 April 2024)

iv. Prevention Measures

Measures of prevention are very effective in the control of winter ulcer disease. Besides vaccination other measures like proper water management, good fish handling and biosecurity are also important in the fight against diseases. The monitoring programs that comprise assessment of fish health and the environment can also help in the early detection of possible outbreaks so that appropriate measures can be taken to minimize the spread of diseases.

2. Piscirickettsiosis: Understanding the Septicemic Condition Affecting Salmonids

Salmonid fish can be infected by a systemic bacteriosis called Piscirickettsiosis, which is subsequently attributed to the parasite *Piscirickettsia salmonis* (Rozas-Serri M 2022). The disease was discovered in 1989 because it resulted in high mortalities among coho salmon that were cultivated in Chile, with levels reaching 30-90% (Valenzuela-Aviles et al., 2022). Thereafter, cases have since occurred in Ireland, Norway, Scotland, and Canada. While impacts may have occurred in both Atlantic and rainbow trout, the OIE (2000) cites coho salmon as the species most affected.

i. Causes and Transmission

*P. salmonis* transmission is generally through horizontal means, although vertical transmission has been proven under some circumstances (Larenas et al., 2008). This required changes in the Chilean salmon farming industry to include the ban on carrier broodstock in a bid to avoiding congenital transmission. Also, external hematophagous isopods have been considered as possible intermediate hosts in the transmission of piscirickettsiosis (OIE, 2000).

ii. Clinical Signs

Affected fish show a range of clinical symptoms such as loss of appetite, reduced feed intake, dark coloration, labored breathing, and swimming at the water surface (OIE, 2000). The first sign that could be identified is the development of popular-waxy, flat and white or superficial hemorrhagic ulcers on the skin. Unfortunately, it should be pointed out that many fish die not exhibiting obvious clinical manifestations. Intrahepatic microscopic and macroscopic pathology revealed by post-mortem examination are as follows: There are multiple small off-white to yellow nodules in the subcapsular areas of the liver measuring as large as 2 cm in diameter.

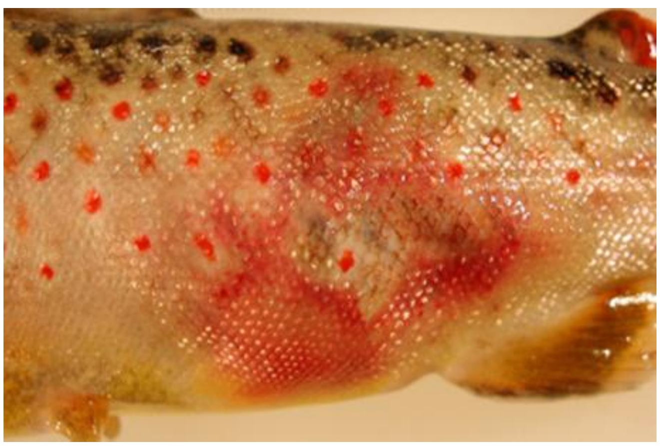

Fig. 2: Clinical manifestation of Piscirickettsiosis in fish, characterized by multifocal hemorrhages and skin lesions on the body surface. These symptoms are typically caused by *Piscirickettsia salmonis*, a significant pathogen in aquaculture (https://doi.org/10.1016/B978-0-12-812211-2.00034-2)

iii. Diagnosis

Piscirickettsiosis diagnosis is complex, and the identification of *P. salmonis* is usually achieved by isolating the bacterium in fish cell lines, CHSE-214, or EPC, which are not supplemented with antibiotics. Primary identification can be performed using light microscopically examined stained kidney or liver imprint by Gram, Giemsa, or acridine orange stains, and then confirmed by serological treatment with immunofluorescence or indirect immunofluorescence (Martínez et al., 2023). The use of ELISA assays for rapid diagnosis has been discussed, while the data regarding the performance of ELISA assays in field samples are scarce. In addition, two protocols have been established based on PCR with the use of nested PCR and the target being the 16S rDNA gene and part of the internal transcribed spacer (ITS) of the ribosomal RNA operon (Yañez et al., 2024). Both techniques play a measurable role in establishing the presence of *P. salmonis* in affected tissues.

iv. Treatment and Prevention

Despite being identified as the major causative agent of piscirickettsiosis, treatment has remained a difficult process because *P. salmonis* is difficult to culture in anything other than specialized fish cell lines, which in practice means treating the fish with antibiotics that are effective against a broad range of bacteria. Currently there are commercial vaccines against *P. salmonis* in Chile but the protection these vaccines offer is questionable because there is lack of published data on protection afforded from experimental and field trials. Recent achievements described for this bacterium include the creation of a monovalent recombinant subunit vaccine, which has demonstrated relatively good efficacy in laboratory tests. Furthermore, a live vaccine, "Renogen" that was developed for bacterial kidney disease has shown to be effective in reducing mortality from *P. salmonis* in Pacific salmon and offers long term protection (Salonius et al., 2006).

v. Broader Implications of Rickettsia-like Organisms (RLOs)

*Piscirickettsia salmonis* is not the only rickettsial or rickettsia-like organism associated with fish disease outbreaks. In addition to salmonids, there have been reports of rickettsial infections in non-salmonid species, including cases of tilapia in Taiwan, blue-eyed plecostomus (*Panaque suttoni*) in the USA, and juvenile seabass in Europe (Mauel et al., 2005). Immunohistochemical studies have indicated antigenic similarities between RLOs affecting European seabass and *P. salmonis*, warranting further investigation into the relationships and potential impacts of these organisms on fish health.

3. Understanding Bacterial Kidney Disease (BKD) in Salmonids

Bacterial kidney disease (BKD, for which the principal etiological agent is the Gram-positive diplobacillus *Renibacterium salmoninarum*) is a chronic systemic disease mainly associated with salmonid fish. This disease is defined by high death rates among farm-raised fish in both freshwater and saltwater a massive economic impact on aquaculture (Ashwath et al., 2024).

i. Epidemiology and Economic Impact

The phenomenon of BKD has been described in different locations, such as North America, Japan, Western Europe, and Chile, and it is particularly important for the populations of Pacific salmon. Due to its distribution in both fresh and salt water bodies alongside to its per-acute and chronic nature, which enables it to develop before the clinical signs are visible, makes it difficult to control. Moreover, since it is transmitted vertically through reproductive products, the disease can also remain in the fish population (Vormedal 2021). Since there are no therapeutic approaches to controlling BKD effectively, studies on its transmission patterns and effects on cultivated fish resources have therefore become relevant for fishery scientists and aquaculturists.

ii. Clinical Features and Diagnosis

As a rule, the clinical signs of BKD are apparent in fish older than one year of age. Early clinical manifestations are apparent on the body surface and are usually mild; they are exophthalmos, distension of the abdomen, and petechial hemorrhages. Intracellularly, *R. salmoninarum* forms granulomatous lesions anywhere in the viscera with prominence in the renal area, where the organisms form characteristic greyish abscesses that lead to considerable renal tissue damage (Varalakshmi et al., 2022). Because of the presence of similar infections by other Gram-positive bacteria including lactic bacteria, clinical signs alone may only suggest the presence of BKD.

As for definitive identification of *R. salmoninarum*, the accurate diagnosis of BKD, therefore, requires accumulating tissue samples from affected fish and bacterial isolation. This process usually employs slide agglutination or immunofluorescence in the detection of sera. Due to these slow growth rate features, taking up to 2-3 weeks to grow and even up to 2 months in subclinical cases at 15°C incubation periods for isolation, the process can be cumbersome and time consuming (Ghasemieshkaftaki, M. 2024).

iii. Immunodiagnostic and Molecular Methods

To overcome the challenges occasioned by culture methods, several immunodiagnostic assays have been invented. Out of them, direct or indirect immunofluorescence tests, and enzyme-linked immunosorbent assays (ELISA) employing polyclonal antibodies directed against the dominant antigen – the heat-stable p57 protein. Although commercially available ELISA kits like Aquarapid-Rs and K-Dtect have been found to increase the level of specificity for detection of the bacterium in the fish tissues, the problem of low sensitivity comes out with the inability to detect carrier fish due to a detection limit of about one thousand five hundred thousand bacteria per gram of tissue (Kowalski et al., 2022).

iv. Vaccination and Control Measures

Now-a-days PCR as well as nested RT-PCR methods are considered to be sensitive diagnostic technique. These techniques have targeted locations inside the 16S rRNA or the p57 gene and are detectable in a range of sample types including kidney tissue and salmonid eggs. Due to suppression of PCR sensitivity by kidney tissue, it is suggested to use lysate of lymphocytes (Wang et al., 2022).

Renogen vaccine from *Arthrobacter davidanieli* is a provent commercial live-vaccine to control the disease, with initial vaccine being developed for the control of Clostrtial diseases. This type of a vaccine also involves an environmental, non-pathogenic bacterium of which has to express certain polysaccharide antigens parallel to *R. salmoninarum*. Cross-sectional studies have long illustrated that Renogen offers subpopulations of significant long-term protection, so that relative percent survival rates exceed 70% among Atlantic salmon at 24 months post-vaccination (Salonius et al., 2006).

4. Vibriosis

Systemic bacterial diseases affect fish and the possibility of aquaculture development in affected areas worldwide, since they threaten the fish stock and the industry's economic potential. The first and most important fish health pathogens commonly known are Listonella (*Vibrio anguillarum*) causing classical vibriosis. This bacterium is more widespread in warm and cold water fish, especially in farms, Atlantic salmon, and rainbow trout (Duman et al., 2022). Another ubiquitous pathogen is *Vibrio ordalii* associated with vibrate disease, particularly in salmonids common in North America, Japan, and Australia. Cold water vibriosis affecting principally the salmonids and cod is due to the bacteria *Vibrio salmonicida* (Zaheen et al., 2022).

i. Symptoms

Pathologic outcomes of *L. anguillarum* infection include hemorrhagic septicemia which is evident by bleeding at the base of fins, exophthalmia and corneal opacity. The clinical presentation of affected fish includes the pale gills and lethargy as the fish reach the end stage of infection. By comparison, *V. ordalii* infections can cause later bacteremia in which the bacterial load in the circulating blood is comparatively lower than that of *L. anguillarum* infections. Further, cold water vibriosis caused by this bacterium is characterized by anemia or luxation, extensive hemorrhage surrounding the internal organs of infected fish (Zaheen et al., 2022).

ii. Treatment

Antibiotics have been widely used and essential in bacterial diseases management in aquaculture. Two types of antibiotics are used recurrently namely oxytetracycline and florfenicol that are efficient against *L. anguillarum* and other vibrios. In the case of *V. salmonicida* treatment involves therapeutic baths in formalin and malachite green which are effective if the disease is treated early. However, the use of antibiotics imposes the problem of antibiotic resistance hence the need for other treatments (Bondad et al., 2023).

iii. Diagnosis

The identification of bacterial ailments affecting fish encompass both conventional culture and molecular approaches. The first approach to *L. anguillarum* identification may involve biochemical characterization; subsequent confirmation could be obtained by the use of serotype specific antisera (MacAulay et al., 2022). Recent development includes PCR-based diagnostic techniques that are based on the rpoN gene for identification (Bondad et al., 2023). Specificity and sensitivity of molecular methods are higher than those of traditional ones, therefore molecular methods are critical in fish pathology.

iv. Prevention

For the fish growers to be able to maintain healthy stocks, there is need to prevent bacterial diseases. These are in as far as pathogen free water are sourced, proper biosecurity measures are embraced during fish transportation, and health checks on the fish stock are conducted among others. Moreover, outbreaks could be prevented by disinfection of ponds and equipment on a regular basis, and the use of vaccines selectively affecting the most important bacterial pathogens is mandatory (MacAulay et al., 2022). Other methods of environmental management are also important in improving the health status of fish through reduction of overcrowding and waterborne diseases.

5. Streptococcosis

Streptococcosis is a reemerging disease that has a great impact on many wild and cultured fish species in the world (Van Doan et al., 2022). The key to effective treatment of this group of diseases is the identification of the bacterial species involved, the symptoms produced by these bacteria and the modes of diagnosis and prevention.

i. Causative Agents

The primary causative agents of streptococcosis include five species recognized as significant fish pathogens: Some of them are, *Lactococcus garvieae, Lactococcus piscium, Streptococcus iniae, Streptococcus agalactiae*, and *Streptococcus parauberis* (Kayansamruaj et al., 2023). These pathogens can cause effects from central nervous system disorder to inflammatory eye bulging and inflammation of the brain and spinal cord (Van Doan et al., 2022). More specifically, *L. garvieae, S. iniae, and S. parauberis* have received more attention as important causes of streptococcosis in marine fish.

ii. Symptoms

The clinical signs of streptococcosis for different agents and at different water temperatures are presented in the table below. Warm-water streptococcosis commonly affects *L. garvieae S. iniae, S. agalactiae* and *S. parauberis* and cause significant mortality rates (Van Doan et al., 2022). It impairs the swimming pattern of the fish, causes exophthalmia and in some instances, meningitis leading to death of fish within affected stocks. On the other hand, cold water streptococcosis attributed mostly to *Lactococcus piscium* and *Vagococcus salmoninarum* occurs at lower temperatures (2022).

iii. Diagnosis

Different procedures could be used for diagnose of streptococcosis beginning with isolation of the Gram-positive cocci in general purpose media though in blood agar there is increased growth. First, screening tests can involve biochemical tests in combination with other selective serological tests namely slide agglutination and fluorescent antibody test (Kayansamruaj et al., 2023). Molecular methods such as ribotyping, RAPD, and PFGE have revealed great utility in differentiating the strains for epidemiological analysis and for determining their pathogenicity (Ramadan 2022; Anwer 2024).

iv. Treatment

Chemotherapy is usually employed in treating streptococcosis but the degree of protection has been found to be variable in light of the bacterial species and mode of administration. Despite the success observed in the use of intraperitoneal vaccines, best *for L.garvieae* and *S.iniae*, these are temporary and act for a period of three to six months at most (Vanamala et al., 2022). Therefore, it is important to enhance the specificity of vaccines to offer improved standard of protection against the strains of viruses that are aggressive in natural infections (Abdallah et al., 2024).

v. Prevention

Measures to control or minimize occurrence of Streptococcosis include management practices in aquaculture that minimize stress factors, maintaining of water quality and exercising good bio security practices. The vaccines are understood to be one of the most important factors that help to avoid catastrophes and reduce the damage. Although vaccines should cover the strains decided to infect in certain farming conditions; for instance, both serotypes I and II of *S. iniae* are required to protect against the disease (Can et al., 2022).

Future prospectus

1. Novel Diagnostic and Treatment Strategies

Development of rapid detection kits and molecular diagnostic tools for pathogen identification. Application of metagenomics and whole-genome sequencing to understand microbial diversity and pathogen evolution.Alternative treatments against antimicrobial resistance, such as phage therapy, antimicrobial peptides, and nanotechnology-based solutions.

2. Improvement of Fish Immunity and Disease Prevention

Probiotics and prebiotics applied for enhancing immunity and gut health in fish.Development of targeted and oral vaccines to effectively prevent disease incidence.Application of management strategies against stress, therefore increasing susceptibility to infections linked to changing environmental conditions.

3. Aquaculture: Environment and Sustainability

Monitoring water quality with the help of IoT and AI for disease prediction. Adopting biosecure facilities, which may also involve a method called integrated multitrophic aquaculture to maintain bacteria in balance in a natural manner.The study of the influence of climate change on pathogen virulence and host immunity, with a view to breeding resistant fish strains.

4. International Collaboration and Public Awareness

Establish global databases of fish pathogens and their genetic profiles.Formulate international guidelines on sustainable aquaculture and disease management.Training farmers and stakeholders in disease prevention, early diagnosis, and best aquaculture practices.Increasing consumer awareness of the importance of sustainable aquaculture for food safety and environmental conservation.

Conclusion

Fish bacterial diseases are among the most important challenges to aquaculture and fisheries, impacting fish health and productivity and, hence global food security. This chapter has outlined major bacterial fish pathogens. The diverse environmental conditions in aquatic ecosystems, along with anthropogenic stressors, facilitate the emergence and spread of these diseases. Poor water quality, high stocking densities, and poor management practices further exacerbate their impact, often leading to epizootics with significant losses. However, improvements in diagnostic techniques, including molecular tools and rapid detection assays, have helped enhance our capability of pathogen identification and monitoring. Novel strategies for disease management, such as vaccine development, probiotics, and immune stimulants, also promise to mitigate their impacts. Yet, the challenge of antibiotic resistance and the need for sustainable practices remain.

Future research should, therefore, be directed at elucidating the complex interactions of the pathogen, host, and environmental factors with holistic approaches to disease prevention. Integrating modern technology with traditional aquaculture will guarantee better health of fish populations for sustainability in the industry and food security at a global level, adding to ecological stability. This knowledge lays the foundation for enhanced aquaculture resilience and ensures protection for aquatic biodiversity.

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