Aquatic Pathogens: Transmission, Impacts, and Zoonotic Potential

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Abstract

Aquatic diseases pose serious hazards to aquaculture, aquatic biodiversity, and public health, especially given their zoonotic potential. The industrialization of fish farming, driven by worldwide seafood demand, has increased the occurrence of bacterial, viral, fungal, and parasitic diseases such as *Vibrio spp., Aeromonas spp., Piscine nodavirus*, and *Cryptosporidium spp.* These infections endanger fish health, cause economic losses in aquaculture, and pose dangers to people via waterborne and foodborne transmission. Poor water quality, climate change, and greater human aquatic interactions have all played a role. Effective management strategies prioritize water quality regulation, vaccination, sanitation, and public health education. Innovations in molecular diagnostics and pathogen management, such as RNA interference and the One Health approach, emphasize integrated solutions to these issues. As global aquaculture grows, interdisciplinary efforts in research, surveillance, and sustainable practices are required to reduce the impact of aquatic diseases on ecosystems, food security, and human health.

Keywords: Aquatic pathogens, Aquaculture, Zoonotic diseases, One Health, Pathogen control

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Introduction

Global demand for seafood has been gradually increasing for decades, and since fisheries production has plateaued, this need has been mostly met by the rise of aquaculture, particularly in developing nations. Aquaculture has become the fastest growing sector in animal food production, with output predicted to nearly double to 93.2 million tons over the next decade. This increase in productivity has been fueled in part by intensive fish farming, which has resulted in an increase in infectious diseases a major limiting factor in aquaculture's expansion (Leung & Bates, 2013).

Aquatic environments are source to a large number of zoonotic diseases that are major public health issues, particularly with the rise of global fisheries and aquaculture. These diseases, which include fungal, viral, bacterial, and parasitic infections, can be transmitted from aquatic animals to people. Some of the most important groups of pathogens involved in diseases of aquatic organisms are a number of pathogens, including gram-negative bacteria. These bacteria have found various ways to control their hosts and defend against environmental threats to sustain themselves (Little et al., 2016).

The risk of zoonotic transmission is increasing because of human water contact for play and seafood (Sheng & Wang, 2021). Because this disease may spread through the water; aquatic diseases pose a serious danger to aquatic ecosystems and human health. To understand their effect on public health and aquaculture, it is necessary to know the knowledge of survival and transmission mechanisms of many aquatic diseases, such as bacteria, viruses and protozoa (Oidtmann et al., 2018).

Types of Aquatic Pathogens

The infections that are caused by bacteria, particularly Aermonas and *Mycobacterium marinum*, are main danger to aquatic organisms and human beings. Climate and ecological properties, as well as many ecosystem elements, control these organisms their occurrence and ability to cause diseases. Regarding the location of the organism, Vibrio species are very well described as being in the aquatic environment, and the organism prefers nutrient-rich conditions. Population density is very much dependent on parameters like temperature and salinity of water (Nongogo & Okoh, 2014; Sacheli et al., 2023).

Aeromonas species are aquatic organisms that are potential pathogens and can potentially infect any host including man. It is probably most likely to cause gastrointestinal symptoms and is associated with waterborne diseases. The conditions that promote the growth of Aeromonas are also encouraged by the factors as, availability of organic matter and temperatures, which are also favorable for other Vibrio species; therefore, there is probability of sharing a niche, which brings high a possibility of infection from both genera to aquatic organisms

(Mohamad et al., 2019; Islam et al., 2023).

Mycobacterium marinum is a pathogenic bacterium present in water and affects fish as well as humans who come in contact with such water. This bacterium was found to be responsible for granulomatous diseases in humans, especially in immunocompromised patients or those who came into contact with contaminated water with an open wound. Described parameters, similarly to those affecting virulence and distribution parameters like salinity and temperature, regulate the environmental stability of *M. marinum*, similar to that of Vibrio and Aeromonas (Mohamad et al., 2019).

The disease associated with aquaculture production is in danger from viral diseases, including fish Rhabdoviruses and Nodaviruses affecting marine and freshwater fish. As a nuisance that causes illness and deaths that affect economic returns to the aquaculture business, it is a relevant virus that produces viral nerve necrosis (VNN) in juvenile fish, the piscine Nodavirus or PNMNV (NNV). Some of these viruses have been known to infect several areas and several fish species, including the European and Asian sea bass (Chérif et al., 2021).

Globally, fungal diseases, more especially those caused by the genera Saprolegnia and Aphanomyces, are major threats to aquatic life and the aquaculture business. In particular, many anglers know some of the representatives of the Saprolegnia species as the 'cotton mold,' the fluffy, filamentous development on the corpse of a sick fish that causes large-scale tissue necrosis and the death of the affected organism in the disease saprolegniosis (Rao, 2023). *A. invadans* has a cosmetic disease of epizootic ulcerative syndrome that is severe for both wild and farmed fish, and these affected fish have ulcerations and coagulative necrotic changes, especially in internal organs (Majeed et al., 2017).

Of all the genera of the parasitic stock, Cryptosporidium species are of especial peril because of their zoonotic qualities and their ability to parasitize such a wide range of hosts, including fish, which can act as a vector for the human populations, hence posing a tremendous health risk to humans and aquatic life. Giardia and Cryptosporidium are two protozoan diseases that are frequently reported to be associated with aquatic environments. Both Giardia and Cryptosporidium have been found to contaminate water, which can cause trouble for public health in the form of dual infections (Schets et al., 2008). Fish helminthes, a diversity of parasitic worms, also increase the health hazards of eating fish. They can impact fish health and pose an additional risk to humans when eating raw or undercooked seafood (Moratal et al., 2020).

The increasing contact between aquatic habitats and human activities has aided the spread of many viruses that can be transmitted from aquatic animals to people, and thus, emerging aquatic illnesses with zoonotic potential are a major hazard to terrestrial and aquatic ecosystems, as well as human health. Table 1 gives a more detailed overview of aquatic pathogens and their transmission route.

Table 1: An Overview of Aquatic Pathogens and Their Threats to Human and Aquatic Health (Johnson & Paull, 2010).

Type of pathogen	Genera/species	Related disease	Host affected	Transmission route
Bacterial	Aeromonas, Mycobacterium, Vibrio	Vibrio infections, Aeromonas infections, Granulomatous infections	Fish and Humans	Through contaminated water
Viral	Rhabdoviruses, Nodaviruses	Fish Rhabdovirus infections, viral nerve necrosis	Fish and Humans	Through poor water
Fungal	Saprolegnia, Aphanomyces	Saprolegniosis, Epizootic ulcerative syndrome	Fish and Humans	Through poor water
Parasitic	Cryptosporidium, Giardia, Helminthes	Cryptosporidiosis, Giardiasis, Fish Helminthes	Fish and Humans	Through poor water
Emerging zoonotic infections	Various viruses, bacteria, and fungi	Zoonotic disease	Fish and humans	Human and aquatic interactions

Transmission Pathways of Aquatic Pathogens

Aquatic infections are transmitted through contact with sick aquatic animals in many ways. The last result can depend on environmental reservoirs and host interactions, as well as the role of specific aquatic animals. Waterborne pathogen transmission through contaminated water is another major public health risk, as water is the origin of many contagious diseases. These infection dynamics can differ greatly according to the specific organism, the environment, and human action (Casanova et al., 2009).

Foodborne transmission by consuming contaminated seafood is one of the largest international public health issues. The danger of foodborne diseases rises with the handling and preparation of seafood. This can be contaminated at different stages of the supply chain, including harvesting, processing, and distribution (Janekrongtham et al., 2021). Aquatic insects are especially active in the transmission of disease, in their interaction with both the terrestrial and aquatic food webs. From their ecological behavior, these insects should be considered as passive carriers and also as active participants in the lifecycle of the pathogen, in eating and egg laying activities (Carolan et al., 2014).

Impact of Aquatic Pathogens on Aquatic Life

Aquatic environment viruses have a large and far-reaching effect on aquatic ecosystems, affecting the growth of aquaculture, fish health, marine biodiversity, and the economic sustainability of fisheries. These pathogens, which include viruses, bacteria, and parasites, are a danger to fish health, particularly in aquaculture where high-density rearing circumstances are widespread. For instance, Motile Aeromonas Septicemia (MAS) in several fish species is caused by *Aeromonas hydrophila*, a widespread pathogen that presents with symptoms of hemorrhagic sepsis and high mortality rates. Due to stress from overpopulation and poor water quality, research has shown that fish in aquaculture systems are particularly susceptible to bacterial infections (Kousar et al., 2019).

From numerous case studies, it is seen that disease outbreaks in aquaculture are devastating. For instance, *Vibrio vulnificus* has been implicated in severe epizootics in cultured fish, leading to significant economic losses and posing a risk to human health because of its zoonotic nature. *Mycobacterium marinum* has been implicated as a pathogen in farmed aquatic animals in South Africa, which is of concern to the aquaculture industry regarding its economic impact. The construction of an aquatic pathogen database indicates that there is an increase in the frequency of disease outbreaks in North American aquaculture, and this is being driven by factors such as global fish trade and climate change (Emmenegger et al., 2011).

Aquatic diseases have a significant economic impact; disease outbreaks result in substantial revenue losses in aquaculture because of high mortality rates and disease control costs. *Aeromonas hydrophila* is a pathogenic bacterium that can cause infections in fish farms, and such infections are often costly to treat and sell affected fish, thereby reducing their market value. The presence of infections in seafood compromises food safety and may cause public health problems and extra revenues for the fisheries sector; therefore, focusing on disease prevention and management is crucial for sustainable and responsible fishing practices (Elmahdi et al., 2016).

Zoonotic Potential of Aquatic Pathogens

Those diseases borne through water, therefore, have the capacity to theory zoonotic, which is a serious health implication. Consistently, it is directly spread and gets transmitted mainly through water and food. Aquatic ecosystems are the source of many viruses that can infect humans and cause outbreaks and health consequences. Zoonotic pathogens include *Cryptosporidium spp. Giardia spp.* bacteria are *Aeromonas spp.* Protozoan parasites such as Cryptosporidium and Giardia are known to cause contamination of water that leads to ailments such as gastrointestinal infections in people. This risk is normally raised through quantity and unrestricted discharge coming from agricultural and urban drainages, where feces containing these health threats are likely to find their way to these water sources, and hence the chances of coming across these diseases by humans (Adell et al., 2014).

Given the fact that waterborne zoonotic infections are capable of precipitating large outbreaks, they are of considerable public health significance. Waterborne disease is the most familiar mode through which it spreads, which is usually obtained from water sources that are contaminated with germs from animal manure. For instance, Cryptosporidium has been found in mussels, marine mammals, which is a risk to beach users and surfers, most especially after rainfall that causes increased runoff (Adell et al., 2014). These include foodborne zoonotic diseases like Cholera and Anisakiasis, which are closely connected with aquatic infections. Anisakiasis is from eating raw or undercooked fish that are infested with nematodes; Cholera, caused mainly by *Vibrio cholerae*, is still a major problem in regions with poor water treatment.

Case studies from history are useful in explaining how the spread of pathogens from water-based sources has occurred. The case of widespread *Streptococcus bovis* infection after consuming manatee meat highlights the potential for zoonotic transmission from aquatic animals. Genomic studies of Cryptosporidium in California sea lions and mussels have found a sharp association of aquatic wildlife with human health hazards, particularly in wet seasons. These cases emphasize the importance of surveillance of aquatic ecosystems for zoonotic diseases to prevent epidemics and protect public health (Adell et al., 2014).

Aquatic Pathogens and Human Health: Risk Factors

Aquatic diseases are a symptom that threat to human health through waterborne exposure, seafood, and climate change. These viruses are mainly transmitted through commercial and extracurricular water contact activities. People working in fishing, aquaculture, and water treatment are especially exposed to zoonotic diseases. For instance, zoonotic infections can be transmitted through direct contact with water or aquatic organisms that are contaminated and thus pose a significant risk to people's health who are in such professions (Leal-Filho et al., 2022).

Through seafood eating, the spread of aquatic diseases occurs primarily because contaminated seafood can contain several zoonotic agents, including antibiotic-resistant strains of Escherichia coli, which are of great concern to consumers. The quality of the water where the seafood is harvested is a safety factor because pollutants and diseases accumulate in the marine life (Divya et al., 2020). Climate change also influences the incidence of water-associated zoonotic diseases in population epidemiology. Therefore, climate change, characterized by fluctuating temperatures and rising precipitation patterns, may promote the spread and survival of pathogens, thereby increasing the incidence of diseases such as schistosomiasis and other waterborne illnesses (Ojeyinka & Omaghomi, 2024).

Some of the aquatic infections are the most severe public health threats globally, and their emergence is accelerated by increased mobility among people. Depending on the venue, contaminated with water or seafood, tourists may get infected with zoonotic diseases. In this era of globalization, the COVID-19 pandemic is a good example of zoonotic diseases that can spread very fast; hence, the need to enhance the surveillance and response mechanism to customers of risks resulting from international travel. The probability of zoonotic spillover increases with the increase in human activities in natural habitats year after year; thus, a need to control these threats through proper collaboration all over the world (Chowdhury et al., 2021).

Diagnosis and Detection of Aquatic Pathogens

It is clear from the above description that the detection and identification of the introduced aquatic pathogens are essential both for humans and aquatic environments. Zoonotic diseases, water-borne diseases, meaning diseases resulting from pathogens found in water that can be passed to human beings through contact with affected water animals, are of interest here, and the following are the methods used to diagnose waterborne zoonotic diseases. The unique features of the PCR process and other molecular strategies have done much in changing the ways pathogens are recognized. For example, quantitative PCR (qPCR) helped discriminate the pathogenic bacteria *Aeromonas veronii*, which is a life-threatening bacterium for fish and humans due to its virulence genes (Zhang et al., 2020).

Some diseases, like *Giardia duodenalis* and *Vibrio cholerae,* are particularly of interest because they can infect human populations and cause epidemics. The fact that numerous viral infections can be carried by migratory birds and that they can thus be sources of contamination of the environment is also noted. The analysis of aquatic pathogens has been enhanced to a great extent owing to the developments in molecular diagnostics. These results show that the molecular diagnostic methods for *A. invadans* are more sensitive than the simple assays that can be used to identify the fish pathogen that causes EUS. These technologies are not only useful for the diagnosis of existing diseases, but they are also useful in the search for new diseases, thus contributing to the growth of the general level of knowledge on aquatic health problems.

Prevention and Control Measures

Control of pathogens in aquaculture is important to ensure the health of aquatic species and to avoid zoonotic disease transmission. Water quality management is another important approach to aquatic disease prevention. Pathogen loads can rise greatly in aquaculture systems when poor water quality prevails. Since these factors influence the survival and multiplication of pathogens, water parameters such as temperature, pH, and dissolved oxygen must be monitored regularly. In addition to water quality control, sanitation, and hygiene measures are crucial in the prevention of zoonotic infections that can affect both aquatic and human populations. Effective sanitation practices include cleaning equipment and facilities regularly, proper disposal of waste, and making sure that people follow hygiene rules.

In this case, management of pathogens in aquaculture is critical to maintain the well-being of aquatic species as well as check the spread of diseases that affect both animals and humans. Another important approach to aquatic disease prevention is water quality management. An increase in pathogen loads is realized in aquaculture systems mainly when water quality is compromised badly. Due to such parameters affecting the survival and reproduction of pathogens, water factors such as temperature, pH, and dissolved oxygen should be checked from time to time. Besides water quality control, sanctity, and hygiene practices are also vital in the eradication of zoonotic diseases that may affect both water Suppliers' inhabitants and other water-living organisms. Some measures of sanitation comprise washing equipment and structures frequently, trash disposal, to ensuring people adhere to sanitation standards (Kabir et al., 2021).

Therefore, immunization or vaccination is also among the critical ways through which incidences of diseases among water creatures can be reduced. They work to decrease the frequency of diseases and improve the wellness of the brought-in species of water by increasing the resistance of the latter against certain sicknesses. Therefore, it can also be effective in disease management in aquaculture systems and antibiotics, and probiotics. On the same note, any type of health promotion initiatives, especially for diseases of the community, concerning zoonotic diseases. Some of the measures that can be taken include having people who deal with animals or animal-derived products develop preventive measures, and educating the public on the dangers of contracting zoonotic diseases (Alemayehu et al., 2021).

Global Health Perspectives on Aquatic Zoonotic Diseases

One Health is a concept of public health that combines human, animal, and environmental health to combat diseases. The World Health Organization (WHO) and the Food and Agriculture Organization (FAO) an important partner in the fight against aquatic zoonotic diseases. This strategy is based on One Health, the relationship between humans, animals, and the environment, and the necessity of cooperation in all sectors for the effective prevention or control of zoonotic diseases. Efforts to prevent and control aquatic zoonotic diseases are encouraged in the WHO and FAO through the use of cross-sector collaboration, while environmental health is noted to be very important. Their activities deal with an interaction of surveillance, regulation, and public health activities to deliver risks of diseases from aquatic sources to the user and to protect human health (Ghareeb & Ali, 2023).

Future Directions in Aquatic Pathogen Research

Current and future emerging zoonotic concerns, breakthroughs in pathogen control and surveillance, and the One Health concept, which includes ecosystem and public health approaches, are all driving significant progress in aquatic pathogen research. Aquatic ecosystems are the source of waterborne diseases that can affect humans. For instance, the spread of multidrug-resistant *Vibrio cholerae* strains in coastal waters is a serious public health threat because these are more adaptable and durable in the environment. The presence of these diseases in aquatic ecosystems calls for comprehensive genomic and epidemiological surveillance of the prevalence and the potential for transmission by zoonotic agents .

Among general trends, the following should be mentioned: Eco-epidemiological changes to future potential emerging hazards, the One Health paradigm use and some developments in the pathogen management and monitoring programs that contribute to the growth of knowledge in Aquatic pathogens. Waterborne diseases that affect human beings are transmitted from the aquatic ecosystem. For instance, Cholera strains which that are multidrug-resistant *Vibrio cholerae* strains that spread in coastal waters are a major public health concern because these are more versatile and long-lasting in the environment. These diseases present in aquatic ecosystems require a global genomic and epidemiologic study of the disease and possible relations to zoonotic vectors (Wartecki & Rzymski, 2020).

The control and monitoring of aquatic pathogens is now being pursued through techniques that have not been widely used before. One appealing solution can be mentioned to be RNA interference (RNAi) technology, which is more ecological than antibiotics. One health approaches that bring together human, animal, and environmental aspects make up this strategy and encourage multiple approaches to eliminating aquatic infections. Research shows that the state of the water in natural environments is a major determinant of infections that may affect water inhabitants as well as people (Perazzolo et al., 2021).

On the other side, more and new approaches appear to have prospects for improving the control and the monitoring of aquatic pathogens. One of the new trends, which has shown some potential, is RNA interference (RNAi) technology that can replace the standard antibiotic treatments with less harm to the environment. One Health is an idea that acknowledges that humans, animals, and the environment are closely linked and that we must fight aquatic infections collectively. It has also been found that the general diffuse contamination of aquatic systems affects the propensity of pathogenic organisms in the life of the aquatic biota and human beings. (Perazzolo et al., 2021).

Conclusion

Aquatic diseases are major threats to aquaculture, aquatic biodiversity, and public health, and are of particular concern because of their zoonotic potential. This is because, as aquaculture continues to grow to meet the rising global demand for seafood, bacterial, viral, fungal, and parasitic diseases become more common and significant. These infections are not only dangerous to aquatic species but also to human health through primary and secondary contact, gastrointestinal, and waterborne pathways. Raising these issues calls for acceptance of the connection between human, animal, and environmental health through the promoted One Health approach. The following are effective ways of reducing

the impact of aquatic pathogen threats: Preserve water quality, improve sanitation, carry out vaccination, and enhance diagnostic facilities. Additionally, worldwide collaboration, new surveillance technology, and novel methods like RNA interference appear to hold promise for lasting control of aquatic health. To develop complete solutions to protect aquatic ecosystems, ensure seafood safety, and protect public health, it is important to understand the complicated transmission pathways and environmental dynamics of aquatic diseases. Ecosystem health and public health measures will be important to integrate as threats in this area continue to rise, and as research progresses.

Reference

Adell, A. D., Smith, W. A., Shapiro, K., Melli, A., & Conrad, P. (2014). Molecular epidemiology of *Cryptosporidium spp.* and *Giardia spp.* in mussels (*Mytilus californianus*) and California sea lions (*Zalophus californianus*) from Central California. *Applied and Environmental Microbiology*, *80*(24), 7732-7740.

Alemayehu, G., Mamo, G., Desta, H., Alemu, B., & Wieland, B. (2021). Knowledge, attitude, and practices to zoonotic disease risks from livestock birth products among smallholder communities in Ethiopia. *One Health*, *12*, 100223-100236.

Carolan, K., Ebong, S. M. À., Garchitorena, A., Landier, J., Sanhueza, D., Texier, G., & Lo Seen, D. (2014). Ecological niche modelling of Hemipteran insects in Cameroon; the paradox of a vector-borne transmission for *Mycobacterium ulcerans*, the causative agent of Buruli ulcer. *International Journal of Health Geographics*, *13*, 1-11.

Casanova, L., Rutala, W. A., Weber, D. J., & Sobsey, M. D. (2009). Survival of surrogate coronaviruses in water. *Water Research*, *43*(7), 1893-1898.

Chérif, N., Zouari, M., Amdouni, F., Mefteh, M., Ksouri, A., Bouhaouala-Zahar, B., & Raouafi, N. (2021). Direct amperometric sensing of fish nodavirus RNA using gold nanoparticle/DNA-based bioconjugates. *Pathogens*, *10*(8), 932-965.

Chowdhury, S., Aleem, M. A., Khan, M. S. I., Hossain, M. E., Ghosh, S., & Rahman, M. Z. (2021). Major zoonotic diseases of public health importance in Bangladesh. *Veterinary Medicine and Science*, *7*(4), 1199-1210.

Divya, P. S., Thajudeen, J., Yousuf, J., Madavan, A., & Abdulla, M. H. (2020). Genetic relatedness, phylogenetic groups, antibiotic resistance, and virulence genes associated with ExPEC in Escherichia coli isolates from finfish and shellfish. *Journal of Food Processing and Preservation*, *44*(11), 14837-44893.

Elmahdi, S., DaSilva, L. V., & Parveen, S. (2016). Antibiotic resistance of *Vibrio parahaemolyticus* and *Vibrio vulnificus* in various countries: a review. *Food Microbiology*, *57*, 128-134.

Emmenegger, E. J., Kentop, E., Thompson, T. M., Pittam, S., Ryan, A., Keon, D., & Kurath, G. (2011). Development of an aquatic pathogen database (AquaPathogen X) and its utilization in tracking emerging fish virus pathogens in North America. *Journal of Fish Diseases*, *34*(8), 579-587.

Ghareeb, O. A., & Ali, Q. A. (2023). Waterborne Zoonotic Bacterial Pathogens. *Texas Journal of Medical Science*, *21*, 63-69.

Islam, M. R., AF, M. H., Islam, M. L., & Banu, G. R. (2023). Total bacterial load and enumeration of pathogenic bacteria vibrio spp., Aeromonas spp. and pseudomonas spp. In the production line of mud crab (Scylla olivacea) hatchery in Bangladesh. *Advance in Animal and Veterinary Sciences*, *11*(6), 968-976.

Janekrongtham, C., Dejburum, P., Sujinpram, S., Rattanathumsakul, T., & Swaddiwudhipong, W. (2022). Outbreak of seafood-related food poisoning from undetectable Vibrio parahaemolyticus-like pathogen, Chiang Mai Province, Thailand, December 2020. *Tropical Medicine & International Health*, *27*(1), 92-98.

Johnson, P. T., & Paull, S. H. (2011). The ecology and emergence of diseases in fresh waters. *Freshwater Biology*, *56*(4), 638-657.

Kabir, A., Roy, S., Begum, K., Kabir, A. H., & Miah, M. S. (2021). Factors influencing sanitation and hygiene practices among students in a public university in Bangladesh. *PLoS One*, *16*(9), e0257663.

Kousar, R., Shafi, N., Andleeb, S., Ali, N. M., Akhtar, T., & Khalid, S. (2019). Assessment and incidence of fish associated bacterial pathogens at hatcheries of Azad Kashmir, Pakistan. *Brazilian Journal of Biology*, *80*(3), 607-614.

Leal-Filho, W., Ternova, L., Parasnis, S. A., Kovaleva, M., & Nagy, G. J. (2022). Climate change and zoonoses: a review of concepts, definitions, and bibliometrics. *International Journal of Environmental Research and Public Health*, *19*(2), 893-899.

Leung, T. L., & Bates, A. E. (2013). More rapid and severe disease outbreaks for aquaculture at the tropics: implications for food security. *Journal of Applied Ecology*, 215-222.

Little, D. C., Newton, R. W., & Beveridge, M. C. M. (2016). Aquaculture: a rapidly growing and significant source of sustainable food? Status, transitions and potential. *Proceedings of the Nutrition Society*, *75*(3), 274-286.

Majeed, M., Kumar, G., Schlosser, S., El-Matbouli, M., & Saleh, M. (2017). In vitro investigations on extracellular proteins secreted by Aphanomyces invadans, the causative agent of epizootic ulcerative syndrome. *Acta Veterinaria Scandinavica*, *59*, 1-9.

Mohamad, N., Amal, M. N. A., Saad, M. Z., Yasin, I. S. M., Zulkiply, N. A., Mustafa, M., & Nasruddin, N. S. (2019). Virulence-associated genes and antibiotic resistance patterns of Vibrio spp. isolated from cultured marine fishes in Malaysia. *BMC Veterinary Research*, *15*, 1-13.

Moratal, S., Dea-Ayuela, M. A., Cardells, J., Marco-Hirs, N. M., Puigcercós, S., Lizana, V., & López-Ramon, J. (2020). Potential risk of three zoonotic protozoa (*Cryptosporidium spp., Giardia duodenalis*, and *Toxoplasma gondii*) transmission from fish consumption. *Foods*, *9*(12), 1913-1945.

Nongogo, V., & Okoh, A. I. (2014). Occurrence of Vibrio pathotypes in the final effluents of five wastewater treatment plants in Amathole and Chris Hani District Municipalities in South Africa. *International Journal of Environmental Research and Public Health*, *11*(8), 7755-7766.

Oidtmann, B., Dixon, P., Way, K., Joiner, C., & Bayley, A. E. (2018). Risk of waterborne virus spread review of survival of relevant fish and crustacean viruses in the aquatic environment and implications for control measures. *Reviews in Aquaculture*, *10*(3), 641-669.

Ojeyinka, O. T., & Omaghomi, T. T. (2024). Climate change and zoonotic diseases: a conceptual framework for predicting and managing health risks in the USA. *GSC Biological and Pharmaceutical Sciences*, *26*(3), 027-036.

Perazzolo, L. M., Li, C., & Somboonwiwat, K. (2021). Aquatic Invertebrate Immunity against Infectious Diseases. *Frontiers in Immunology*, *12*, 762082.

Rao, P. K. (2023). Economically important freshwater fishes infected with fungi causes EUS. *World Journal of Advanced Research and Reviews*, *17*(1), 605-609.

Sacheli, R., Philippe, C., Meex, C., Mzougui, S., Melin, P., & Hayette, M. P. (2023). Occurrence of Vibrio spp. in Selected Recreational Water Bodies in Belgium during 2021 Bathing Season. *International Journal of Environmental Research and Public Health*, *20*(20), 6932.

Schets, F. M., Van Wijnen, J. H., Schijven, J. F., Schoon, H., & de Roda Husman, A. M. (2008). Monitoring of waterborne pathogens in surface waters in Amsterdam, the Netherlands, and the potential health risk associated with exposure to Cryptosporidium and Giardia in these waters. *Applied and Environmental Microbiology*, *74*(7), 2069-2078.

Sheng, L., & Wang, L. (2021). The microbial safety of fish and fish products: Recent advances in understanding its significance, contamination sources, and control strategies. *Comprehensive Reviews in Food Science and Food Safety*, *20*(1), 738-786.

Wartecki, A., & Rzymski, P. (2020). On the coronaviruses and their associations with the aquatic environment and wastewater. *Water*, *12*(6), 1598-1667.

Zhang, H. P., Kang, Y. H., Kong, L. C., Ju, A. Q., Wang, Y. M., Muhammad, I., & Ma, H. X. (2020). Functional analysis of hisJ in Aeromonas veronii reveals a key role in virulence. *Annals of the New York Academy of Sciences*, *1465*(1), 146-160.