Viral Diseases of Aquatic Life & their Zoonotic Impact

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Abstract

In an aquatic ecosystem, viral infections adversely affect the health status of living creatures present in the water that is either hot or cold. In this chapter, a precise review of viral agents' impact on fishes, mollusks, and other water-living bodies is given. Shrimp are discussed in detail along with their viral agents. The economic losses with environmental effects are discussed briefly. The steps of prevention, control measures, and diagnostic tools with vaccination protocols are also given. The role of wet markets in the spread of viral infections, their controlling parameters, and preventions are given. The significance of the One Health approach to deal with viral infections is also discussed here; the pandemic of COVID-19 in relation to wet markets is also elaborated with the past scenario of China (Wuhan). The importance of a surveillance system is a key to overcoming zoonotic viral infections of aquatic life. Water is an important reservoir for aquatic pathogens: bacteria, viruses, parasites, and fungi.

Keywords: Aquatic ecosystem, Viral agents, Economic losses, Control measures

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Introduction

The viral challenges in aquatic ecosystems a zoonosis (or zoonotic disease) refers to an infectious disease that can be transmitted between animals and humans (Han et al., 2016). These pathogens, which typically reside within animal populations, can be transferred to humans either directly or through intermediaries like vectors (Wolfe et al., 2007). In aquatic systems, zoonotic diseases are generally not considered significant (Shamsi, 2019). When such diseases do occur, the cases are far fewer in number compared to other zoonotic diseases found in humans or animals, such as campylobacteriosis or salmonellosis (Zorriehzahra & Talebi, 2021). For instance, a study found that approximately 260,000 people in the USA become ill annually due to contaminated fish, with fish being one of the most common culprits in foodborne outbreaks (Barrett et al., 2017). Many diseases found in aquatic organisms are classified as emerging diseases. According to the World Health Organization (WHO), these are diseases that either appear for the first time in a population or are rapidly increasing in frequency or geographical distribution. A characteristic of emerging diseases is the limited information regarding their zoonotic potential (Zorriehzahra et al., 2014; Farzadnia & Naeemipour, 2020). The immune system plays a crucial role in determining the severity of these aquatic zoonotic diseases (Raissy, 2017).

Aquatic Virology: An Emerging Frontier

Global environmental changes are expected to affect every component of ecosystems, including microorganisms such as bacteria, archaea, eukaryotic microbes, and viruses in aquatic systems, all of which play vital roles as both agents and recipients of climate change (Danovaro et al., 2011; Hutchins & Fu, 2017). Changes in ocean currents, the stratification of water bodies, and fluctuations in light and nutrient availability will likely influence CO_2 dynamics and the carbon cycle (Bauer et al., 2013; Finke et al., 2017). Because microbes are integral to ecosystem processes, much focus has been placed on how rapid climate shifts may impact microbial communities, especially in the Arctic and Antarctic (e.g., the European Project on Ocean Acidification, EPOCA). Any decline or alteration in these microbial ecosystems will affect food webs and biogeochemical cycles, making polar microbiota key indicators and amplifiers of global change (Vincent, 2010). Virus communities in natural aquatic environments exhibit significant dynamism, with their abundance and diversity often fluctuating based on the availability of hosts. The viral populations tend to be larger in freshwater systems compared to marine environments, and peak concentrations are typically found in highly productive estuaries and lakes (Parikka et al., 2017). The viral particles are more prevalent in eutrophic waters than in oligotrophic ones (Parikka et al., 2017). A vital regulator of aquatic systems, viruses impact microbial life and have an impact on more general ecological processes like carbon cycling. The viral ecology will remain crucial to comprehending the ways that human activity and climate change affect aquatic food webs (Brussaard et al., 2008; Zimmerman et al., 2020). The microbial growth, respiration, and carbon absorption are anticipated to be impacted by rising water temperatures, which will impact virus-host interactions in these systems (Danovaro et al., 2011). Among the tiniest and most prevalent biological organisms in aquatic environments are viruses, particularly bacteriophages. Since they are usually 10–15 times more prevalent than their microbial hosts, they significantly increase the turnover of carbon (Suttle, 2005). The significance of viruses for ecological balance is further demonstrated by the fact that viral infections are a leading source of prokaryotic mortality in aquatic settings (Suttle, 2007; Brussaard et al., 2008).

Key Viral Pathogens in Fish: A Growing Concern

The Food and Agricultural Organization (FAO) of the United Nations estimates that food and feed production must increase to 70% by 2050 to feed the world's growing population. The world's fastest-growing animal food sector, aquaculture, faces a number of challenges, including new diseases caused by bacteria, fungi, viruses, oomycetes, amoebas, and other parasites that limit fish and shellfish production. Antibiotics are commonly used to treat bacterial infections in fish (Romero et al., 2012). However, as a long-term strategy for managing fish sickness, probiotics-beneficial bacteria introduced to aquaculture settings- are showing promise. Numerous studies have examined the use of probiotics such as bacteria, bacteriophages, fungi, and yeasts- in aquaculture (Newaj-Fyzul & Austin, 2015; Banerjee & Ray, 2017).

Histamine, viruses, parasites, biotoxins, and bacterial infections are linked to outbreaks of fish and shellfish, particularly when they are undercooked or uncooked (Galaviz-Silva et al., 2009). Fish naturally harbor a wide variety of viruses, according to metatranscriptomic analyses. These viruses include DNA viruses like parvoviruses, papillomaviruses, and hepadnaviruses, as well as relatives of well-known human pathogens like SARS-CoV-2, hepatitis C, influenza, filoviruses, and paramyxoviruses (Lauber et al., 2017; Shi et al., 2018; Liu et al., 2020; Costa et al., 2021; Geoghegan et al., 2021; Miller et al., 2021; Kraberger et al., 2022; Tartor et al., 2022; Costa et al., 2024). Yearly, emerging viral infections in aquatic life causes loss of up to $6 billion worldwide (Stentiford et al., 2017). In addition, a number of viral infections have lately led to outbreaks both in domestic and wild aquatic plants (Scherbatskoy et al., 2020; Soto et al., 2020; Hierweger et al., 2021; Edwards et al., 2022; Fu et al., 2022; Liu et al., 2022). Reoviruses, flaviviruses, Hantaviruses, picornaviruses, caliciviruses, iridoviruses, and parvoviruses are among these viruses. Their outbreaks have also affected endangered species badly, putting them at risk of extinction (Mordecai et al., 2021).

Shrimp and Shellfish Viruses: Beyond Marine Boundaries

Fish farming along with husbandary practices of other aquatic life, or aquaculture, has an ancient history; evidence indicates to ancient China as the earliest known location for this, about 4,000 years ago. The Old Testament and Middle Kingdom Egyptian hieroglyphics both points to fish ponds (2050–1652 BC). The Roman Empire, also created fish farms & new archeological research in the Amazon region of Bolivia has indicated that advanced fish weirs existed before the Hispanic era (Higginbotham 1997; Erickson 2000). However, shrimp farming significantly affected by disease outbreaks. Since 1981, a series of viruses have emerged in Asia and the Americas, causing die-offs at large scale and putting the economic stability of the shrimp industry at risk (Walker and Mohan, 2009). As arthropods, shrimp viruses are often closely related to those that infect insects, such as densoviruses, dicistroviruses, and baculoviruses. The adaptive and innate immune mechanisms typically present in vertebrates, such as antibodies, lymphocytes, and interferons are lacking in shrimps proving a health challenge to shrimp population. Although some toll-like receptors have been identified in shrimp, their role in antiviral defense remains unclear (Yang et al., 2007; Labreuche et al., 2009). A unique feature of shrimp viruses is their ability to cause persistent, mild infections, which can be widespread in apparently healthy populations (Hsu et al., 1999; Nunan et al., 2001; Walker et al., 2001; Chakraborty et al., 2002; Tan et al., 2009). In addition, horizontal transmission is common, and the spread of the disease intensifies with increase in viral load. The basic complication in diagnosis, detection, and treatment strategies in the shrimp viruses, is the unique aspect of the viruses' ability to infect with multiple viruses simultaneously or sequentially (Flegel et al., 2004; Hoa et al., 2005).

Zoonotic Viruses: Crossing the Species Barrier

The eating of contaminated seafood, particularly ready-to-eat fisheries products and shellfish exposed to fecal contamination, is becoming a significant public health problem due to the rise in acute gastroenteritis caused by Noroviruses (NoV). This newly discovered foodborne disease poses a health concern and causes large financial losses globally (Pavoni et al., 2013; Li et al., 2014; Kittigul et al., 2016; Marsh et al., 2018). The family *Caliciviridae* includes the non-enveloped, positive-sense, single-stranded RNA viruses known as noroviruses. In addition to its sole species, the Norwalk virus, the genus *Norovirus* is further subdivided into seven genogroups (GI-GVII) (Atmar et al., 2019). The genogroups GI and GII are the most commonly linked to infections in humans (Vinje et al., 2000). Nausea, vomiting, diarrhea, and stomach pain are the usual symptoms of gastroenteritis caused by NoV. Secondary symptoms include headaches, muscular pains, exhaustion, low-grade fever, and taste loss. Twelve to forty-eight hours after consuming tainted food, these symptoms often manifest. Though protracted infections, enteropathy, and malabsorption may occur in people with weakened immune systems, the condition usually resolves on its own (Center of Disease Control and Prevention (CDC), 2016).

The Role of Wet Markets in Zoonotic Viral Spillover

This led to demands that these marketplaces be permanently closed in China and throughout the world (Walzer & Kang, 2020). Wet markets in East and Southeast Asia, usually have rows of sellers in partially or completely open-air environments, where they sell fresh, perishable items like vegetables and meat (Zhong et al., 2020). The possibility of disease outbreaks and the possible intensity of their effects are the factors in the risk connected with the wet markets. For instance, domesticated animals may be more susceptible to recurrent zoonotic illnesses because of their increased human interaction (Morand et al., 2014). People may less likely exposed to wild animals, but this can cause serious disease outbreaks like SARS, Ebola, monkeypox, Nipah virus, and COVID-19. Mostly these outbreaks are thought to have started in marketplaces, farms, or pet shops that sell wild animals (Scheffers et al., 2019). Generally speaking, zoonotic transmission, virus replication, and genetic mutation are usually involved in the evolution of infectious diseases (EIDs) in humans (Jones et al., 2008; Parrish et al., 2008; Kreuder Johnson et al., 2015).

Diagnostic Tools for Viral Detection in Aquatic Species

A third-generation sequencing platform introduced in 2014, by Oxford Nanopore Technologies, covers number of challenges of traditional next-generation sequencing (NGS), giving long, accurate reads in real-time through a compact, portable device weighs 90 gram (Laver et al., 2015). Due to accuracy limits nanopore sequencing is not yet widely used in disease diagnosis for aquatic life, it shows great potential for identifying novel pathogens. The U.S. Food and Drug Administration (FDA) approved emergency use of SARS-CoV-2 test kits based on nanopore sequencing technology during the COVID-19 pandemic (FDA, 2023). For viral disease diagnosis in aquaculture, cell culture remains the gold standard, followed by polymerase chain reaction (PCR) testing. Meanwhile, MALDI-TOF mass spectrometry is more suited to bacterial disease detection (Assis et al., 2017).

Advances in Vaccination for Aquatic Viral Pathogens

For bacterial infections like yersiniosis and vibriosis, vaccines continue to be among the most effective and widely used commercial vaccines in the industry. In 1970s, first vaccination in aquatic life began with early focus on bacterial infections. A major development in recent years, is DNA vaccine that involve the administration of a plasmid encoding the antigen rather than using the antigen itself. Both humoral and cellular immune responses are stimulated by these vaccines (Perrie et al., 2008). At present, there are three live, modified vaccines licensed in the USA, including those for *Edwardsiella ictaluri* (used in catfish to combat enteric septicemia), Arthrobacter species (for bacterial kidney disease in salmonids), and Flavobacterium columnare (for columnaris disease in catfish) (Klesius & Pridgeon, 2014).

Conclusion

In conclusion of this chapter, our readers are well aware of the significant threats of all viruses of zoonotic potential in an aquatic ecosystem. The effects are not only confined to sea creatures but drastically affect the One Health pool. The possible solution to overcome these effects is to mitigate the risk factors associated with them. Further research on aquatic life and the zoonotic potential of aquatic viruses is needed. With the advancement in diagnostics, treatment, and vaccination protocols, there would be better control on the spread of viral diseases in aquatic life; it would be beneficial for humans, animals, and the environment as well.

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