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An Overview On: Bacterial Fish Zoonoses

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ABSTRACT

The word "zoonosis" describes a disease that people can catch from domestic or wild animals. Zoonoses demand particular care due to the extensive traffic in live aquatic animals and their products, as well as the global expansion of aquaculture. Due to the variety of transmission channels and the fact that many zoonotic diseases do not cause sickness in aquatic organisms, pathogen interactions between aquatic species and humans are complex. The following groupings can be used to classify zoonotic diseases: a) skin conditions brought on by contact with aquatic creatures or their byproducts b) Zoonotic diseases that can be contracted by eating or touching fish. C) Foodborne diseases caused on by ingesting raw or undercooked aquatic products. From a microbiological perspective, fish and related foods are a group that should be avoided. It is not advisable for people with weakened immune systems to handle fish or maintain fish aquariums. When handling fish or cleaning fish tanks, they should put on thick, waterproof gloves. As a result, it is essential to conduct ongoing epidemiological surveillance of zoonotic bacteria identified in fish and their impacts on public health.

Keywords: *Aeromonas* Spp.; Contact; *C. Perfringens*; Fish zoonoses and Foodborne

INTRODUCTION

Zoonosis (plural zoonoses for pleural) is an infectious disease that can be spread from one species of animal to another through a variety of different routes, such as direct contact through ingestion, respiration, skin-to-mucous membrane contact, penetration through abrasions or wounds, and even vectors (Han *et al.,* 2016; Rahman *et al.*, 2020). The widespread consensus is that aquatic animals don't typically have many significant zoonotic infections (Shamsi, 2019). Due to a lack of awareness, understanding, and clinical symptoms as well as a lack of surveillance and monitoring of zoonotic agents in aquatic species, the number of annual reported cases is low and underestimated when compared to other zoonotic illnesses in diverse animal species or humans. However, for individuals who receive a diagnosis, the effects could be fatal (Zorriehzahra and Talebi, 2021). But there are mainly just two ways for human diseases to manifest themselves. Consuming raw or undercooked fish and drinking water or other liquids contaminated with infected fish faeces or mucus are the first two causes. The infectious agent is touched in the second scenario through open wounds or skin abrasions. 15% of zoonotic infections that originate in fish are spread in several ways, compared to 46% that are transmitted orally. According to Raissy (2017), the rates of skin contact when handling fish and drinking water contaminated with harmful organisms are 24 and 19%, respectively. Since many instances are not recorded or diagnosed, data on the prevalence and incidence of topically acquired zoonotic illnesses from fish are limited, but they should be taken into account as a severe threat to public health (Aggarwal and Ramachandran, 2020). The current review endeavour was motivated by the lack of knowledge regarding the occurrence and prevalence of zoonotic factors. The different hosts, geographic distribution, and impacts of seasonality on infection prevalence all require further study. It is also vital to have a better grasp of the morphological identification of pathogens in order to enhance our knowledge of the food industry, biosecurity, and medical practises, as well as to better understand the prevalence of diseases in their environments.

1. Epidemiology:

1.1. Source and route of transmission of zoonotic bacterial fish diseases

The diversity of transmission methods and the fact that many zoonotic diseases do not sicken aquatic organisms make it difficult for pathogens to interact with humans and aquatic species. Therefore, even healthy-looking fish have the potential to transmit illnesses to carriers who are otherwise unaffected. Additionally, commensal bacteria that often cause little harm to aquatic organisms may eventually cause zoonotic diseases that affect people. Another issue with pathogen detection in fish is that many clinical indications of sickness in aquatic species are different from those that manifest in ill humans (Lowry and Smith, 2007).

Humans can contract zoonotic illnesses through consuming tainted seafood or water, getting stung or bitten, suffering spine or pincer injuries, or coming into contact with open wounds on the handler. People who frequently interact with fish, its byproducts, or its environment (such fishermen or those who work in the fish processing industry) are at higher risk. Someone may be more vulnerable if their immune systems are weak. Iwamoto *et al.* (2010) discovered a consistent link between seasonality (i.e., higher *Vibrio* levels in warmer water) and dietary choices, such as live and fresh seafood, and human seafood-related illnesses.

1.2. Humans at risk:

Aquaculture experts, fish culturists, processors, handlers, as well as commercial and recreational fisherman and fisherwomen, are the groups most at risk of topically acquiring zoonotic diseases from fish. They frequently come into touch with fish, and the warm, humid environment inside is ideal for bacterial growth. According to Haenen *et al.* (2013), immunocompromised people are more prone to infection from invasion through open skin wounds.

1.3. Environmental risk factors:

At sampling sites, the presence and concentrations of naturally occurring bacteria were primarily influenced by the ambient temperature and salinity, and they changed seasonally and geographically as a result. About 80% of the change in bacterial counts and 12% of the variation in species composition could be attributed to temperature and salinity alone. In a number of settings, changes in the species composition of aquatic bacteria have been linked to elements like nitrogen, phosphorus, dissolved oxygen, and chlorophyll a (Jeffries *et al.,* 2016). In general, dissolved oxygen content and bacterial concentrations were closely associated (Morii and Kasama, 1995).

When fish are kept at temperatures between 20 °C and 30 °C, certain of pathogenic bacteria may survive and become contact-zoonotic, or hazardous to people when they come into close contact with infected fish or fish water, especially if they have damaged skin or compromised immune systems (Haenen *et al.,* 2013). Although this risk exists in open fish cultures, it may be even greater in contaminated warm water recirculation aquaculture systems, including aquaponics systems. Contaminated water is recirculated in these systems, and bacteria could grow, posing a risk to those who work in fish culture (El-Sayed, 2006).

1.4. ***Pathogen–Host Association***

From one species of fish to another, there might be significant differences in susceptibility and clinical indications of infection brought on by a pathogen. Divergences in the fish's immune systems are a crucial factor in these changes. The varied histological responses of cod and Atlantic salmon to atypical furunculosis serve as an illustration of this. The cod response is characterized by widespread granuloma development, whereas the salmon response is characterized by bleeding and localized cellular necrosis (Magnadottir *et al.*, 2002). For example, cod exhibits a minimal or no antibody response to a variety of bacterial infections, in contrast to Atlantic salmon (Lund *et al.,* 2008).

2. Public health importance

Fish pathogenic bacteria frequently cause serious illnesses in highly farmed fish populations in fish farms. Fish illnesses caused by bacteria are routinely treated with antibiotics put in medicated feed. Antibiotic resistance became a problem against the majority of fish pathogens in infected fish farms. In order to combat diseases, modern fish farming increasingly relies on vaccination protocols and improved management (Bowden *et al.,* 2003). For instance, both pathogenic and non-pathogenic bacteria have been detected in several fish parts in Ethiopia. The harmful zoonotic bacteria *Edwardsiella tarda* has been found in fish that appeared to be in good health in Lake Ziway and Lake Tana. Eating undercooked fish meals and handling fish by hand enhance the risk of infection for the general public (Nuru, 2007). With the exception of a few published studies, Ethiopian research on these themes is scarce and poor, despite the fact that bacterial diseases are the primary cause of high mortality rates, monetary losses, and bacterial zoonoses around the world. As far as the researchers are aware, no research has ever been done on Lake Hayiq (Lugo) (Tsfaye *et al.,* 2018). Wendwesen *et al.* (2017) discovered a prevalence of 65% in frozen raw fillet obtained from Lakes Abaya and Chamo despite the fact that there has been little research on the occurrence of *S. aureus* in fish and fish products in Ethiopia. This may also demonstrate that *S. aureus* can endure subfreezing conditions, posing safety issues for the general populace (Sorsa *et al.*, 2019). Children, the elderly, and people with compromised immune systems should avoid eating fresh fish that has been infected with *A. hydrophila*, according to several authors (Kebede and Habtamu, 2016). It may grow at cold temperatures and is the cause of food- and water-borne illnesses that can affect people in different ways, ranging from mild gastroenteritis to fatal septicemia (Niamah, 2012).

Additionally, a number of fish-related bacterial zoonotic outbreaks have been reported in the last ten years, two listeriosis outbreaks as a result of smoked fish consumption (Lassen *et al.*, 2016), two botulism outbreaks occurred after eating fish in Norway and Germany (Eriksen *et al.*, 2004), 2015 epidemic of severe *Streptococcus agalactiae* sequence type 283 infections in Singapore associated with the consumption of raw freshwater fish (Kalimuddin *et al.*, 2017) and the large outbreak in the Netherlands related to consumption of smoked salmon contaminated with *Salmonella thompson* (Friesema *et al.*, 2014).

3. Economic impact

Both marine and freshwater farmed fish, such as tilapia, catfish, carp, trout, salmon, bass, perch, sturgeon, and eels, are severely harmed by bacterial infections. An estimated $120 million in economic losses per year were attributed to three bacterial fish infections in China between 1990 and 1992: *Aeromonas hydrophila*, *Yersinia ruckeri*, and *Vibrio fluvialis*. The global economic impact of bacterial infections on the productivity of aquaculture could be in the range of hundreds of millions to billions of dollars yearly given that the estimated value of aquaculture production in 2009 was $105.3 billion (Qi, 2002).

The main cause of major fish deaths and economic losses worldwide is bacterial infections (Eissa *et al.*, 2010). There are several bacteria that can infect and kill both fish and people, according to Austin *et al.* (2005). The bacterium *Edwardsiella tarda* (*E. tarda*) is the cause of fish gangrene, an emphysematous putrefactive disease that occasionally affects humans and fish and causes large economic losses for fish in many countries (Gauthier, 2015).

4. Zoonotic bacterial pathogens of fish

4.1. Zoonotic fish bacterial pathogens transmitted through contact:

4.1.1. Streptococcaceae

A family of Gram-positive zoonotic bacteria where the systemic streptococcosis is a serious economic hazard in whole the world (Iregui *et al.*, 2016). These pathogens are considered emergent zoonotic agents when humans meet fish. In farmed fish species, meningoencephalitis and deaths have been declared (Novotny *et al.*, 2004). There are two routes for zoonotic illness to spread from fish to humans: direct contact with sick or dead fish, or even indirect interaction with polluted water. The primary species that cause fish streptococcosis, according to Pradeep *et al.* (2016), are *S. iniae*, *S. difficile*, *S. shiloi*, *S. dysgalactiae*, *S. difficilis*, and *S. agalactiae*. Frogs, people, and freshwater and marine fish have all been identified to harbour GBS ST283 strains (Zadoks *et al.*, 2020). Different fish species exhibit various clinical symptoms. However, exophthalmia, eye opacity, loss of orientation, stomach distention, anorexia, irregular swimming, darkening and hemorrhagic skin, and ultimately death, are the most typical signs. In addition, the bacteria are now responsible for significant rates of illness and mortality in both freshwater and saltwater fish (Leal *et al.*, 2019).

The bacteria are found in the organs and tissues that fish need for their immune systems, such as the gills, spleen, kidneys, tissues, and liver. Studies on the pathogenicity of the pathogen (Iregui *et al.*, 2016) revealed that *S. agalactiae* primarily entered the tilapia gastrointestinal tract through the mucosa and intestinal layers. After touching infected fish, humans may suffer cellulite, meningitis, endocarditis, severe systemic infections, lymphadenitis, septicemia, suppurating ulcers, arthritis, and in rare circumstances, fatality (Haenen *et al.*, 2013).

4.1.2. Erysipelotrichaceae

A Gram-positive microorganism linked to fish zoonoses. It has a connection to marine mammals and can lead to acute sepsis or skin conditions (Boylan, 2011). The most significant member, *E. rhusiopathiae* (*E. insidiosa*), is responsible for sickness in both people and animals with a tendency to the arterial walls, connective tissues, and skin. Myositis, cellulitis and necrotizing dermatitis are examples of clinical presentations (Balootaki *et al.*, 2017). *E. piscisicarius*, a newly discovered species of ornamental fish, has recently been discovered in fish (Pomaranski *et al.*, 2020). In hot seasons, this soil saprophyte can readily cause erysipeloid in fish salesmen and handlers (Novotny *et al.*, 2004). By touching live or dead fish, or fish mucus harbouring the germs, people can become infected with bacteria (Boylan, 2011). It should be mentioned that fish do not get sick from *E. rhusiopathiae*. However, because it can survive for a long time on the fish's exterior mucus, it can spread to people and result in erysipeloid illness (Nielsen *et al.*, 2018). Endocarditis, septicemia, and skin infections, particularly on the hands, can all be brought on by *E. rhusiopathiae*. Fishermen and veterinarians are among individuals who have a greater risk of developing an erysipelothrix infection. The first instance of human endocarditis disease was caused by this bacteria and was linked to operations carried out off the coast of Norway in 2017 (Nielsen *et al.*, 2018).

4.1.3. Mycobacteriaceae

The *Mycobacteriaceae* family, which encompasses different diseases that affect people, animals, reptiles, and fish, is made up of gram-positive, acid-fast, aerobic, non-motile bacilli known as *Mycobacterium* spp. (Delghandi *et al.*, 2020b). According to Hashish *et al.* (2018), mycotuberculosis, a frequent disease of marine, freshwater, and brackish water fish, is a significant factor in the decline of both farmed and wild fish. More than 150 different fish species have been reported to have Non-tuberculosis *Mycobacterium* (NTM) infections, and this zoonotic form of the disease raises worries for the general public's health (Gcebe *et al.*, 2018). The majority of fish species are susceptible to vertical and lateral spread of *Mycobacterium* spp. (Puk and Guz, 2020). Due to the diversity of the host species and the diversity of bacterial species, clinical indications of infected fish can include lethargy, coloration, stomach distention, exophthalmia, skin lesions, and even mortality (Delghandi *et al.*, 2020a). Exophthalmia, skin rashes, and sometimes even death are other symptoms. The illness can be found in a variety of fish organs, including the eyes, gills, liver, kidneys, and spleen, as a result of the infection's ability to spread through the circulatory and lymphatic systems (Chinabut, 1999). Nodules in internal organs and enlarged liver, kidney, and spleen are other indications that a fish is afflicted (Delghandi *et al.*, 2020a). Boylan (2011) maintained that sick and asymptomatic fish are long-term carriers or dispersers of the bacteria, but Bhambri *et al.* (2009) contended that contact with polluted aquatic life and water frequently results in human infections. There are 120 species of Mycobacterium that have been identified, including *M. avescens*, *M. chelonae*, *M. fortuitum*, *M. gordonae*, and *M. Both*, short-term and long-term problems may result from their infections (Delghandi *et al.*, 2020a). People regularly encounter these mycobacteria, which can cause severe necrotic lesions, granulomatous skin lesions, and deep tissue infections in tendons and bones. Even yet, people with compromised immune systems are nonetheless susceptible to rare extra- and systemic respiratory illnesses. According to Delghandi *et al.* (2020a), sporadic disorders include osteomyelitis, arthritis, and bronchitis. In those with compromised immune systems, mycobacteriosis can result in systemic illness and even death (Boylan, 2011). Marine and decorative fish are both present in freshwater. The four most common *Mycobacterium* species determine when outbreaks start. These four species are *M. marinum*, *M. fortuitum*, *M. gordonae*, and *M. chelonae*, with *M. marinum* being the most prominent. In Trinidad and Tobago, ornamental fish utilised for trade were found to have piscine mycobacteriosis (Phillips Savage *et al.*, 2022).

4.2. Zoonotic bacteria due to fish ingestion (foodborne zoonoses):

4.2.1. Vibrionaceae

Aquaculture workers and consumers of aquatic goods are at danger from zoonotic transmission of a Gram-negative bacterium that causes vibriosis in both people and animals (Austin, 2010). The increasing employment of antibiotics in cultured systems has led to an increase in antibiotic resistance against the bacterium, making vibriosis a potentially serious disease for fish (Helmi *et al.*, 2020). Many *Vibrio* species can spread disease to humans through infected fish and skin sores, and they can survive in both freshwater and brackish water. *V. metschnikovi*, *V. vulnificus*, *V. cholerae*, *V. damselae*, *V. hollisae*, *V. alginolyticus*, and *V. parahaemolyticus* are some of the species that can infect individuals (Boylan, 2011).

The most common *Vibrio* species found in marine fish are *V. cholera*, *V. parahaemolyticus*, and *V. vulnificus* (Huzmi *et al.*, 2019). Important species like *V. alginolyticus*, *V. anguillarum*, *V. campbellii*, *V. harvey*, and *V. parahaemolyticus* have been identified in infected fish. Lethargy, skin lesions, exophthalmia, and mortality are just a few of the non-specific clinical indications that fish with a *Vibrio* infection may display. Additional signs and symptoms include a bloated spleen, tail rot, intestinal inflammation, abdominal dropsy, scale shedding, epidermal haemorrhage, and pop-eye, according to Huzmi *et al.* (2019). Hernandez- Cabanyero and Amaro (2020) claim that the transmission of zoonotic *Vibrio* species from fish to humans might result in issues including lesions, septicemia, erythema, and tissue necrosis. Seafood-related *V. parahaemolyticus* infections can occur as ready-to-eat seafood items like raw fish slices gain popularity. Humans may get acute septicemia after consuming raw shellfish, whereas subsequent septicemia happens when wounds are exposed to seawater (You *et al.*, 2021).

4.2.2. Pseudomonadaceae

Pseudomonas is an opportunistic Gram-negative bacillus that can cause food poisoning (Yagoub, 2009). Because it is a part of the natural microbiota, it is problematic for fish under stress (Algammal *et al.*, 2020). However, *Pseudomonas aeruginosa*, *P. putida*, *P. anguilliseptica*, and *P. fluorescens* are *Pseudomonas* septicemic agents in fish. According to Guzman *et al.* (1986), *P. septicemia* has been found in brackish, marine, and freshwater settings. Some of the pathogen's clinical signs include unusual skin-surface bleeding, exophthalmia, hazy eyes, ulceration, detached scales, darkening of the skin, abdominal distention, ascites, and blocked gills.

The bulk of symptoms, according to Ismail *et al.* (2017), are triggered by bacterial extracellular toxins and enzymes. The spread of bacteria that are resistant to antibiotics, particularly *Pseudomonas*, a critical public health concern, is significantly facilitated by close human-fish interaction (Fernandes *et al.*, 2018).

4.2.3. Staphylococcus aureus

The presence of germs is recognized as an infection before or after harvest because *Staphylococcus aureus* infections, particularly methicillin-resistant *S. aureus* (MRSA) infections, are becoming more prevalent in fish. Therefore, Staphylococcus is a target since it is thought to be crucial for fish food (Vaiyapuri *et al.,* 2019). People handling food who have *S. aureus* on their skin or mucous membranes can contaminate fish, according to research by Obaidat *et al.* (2015). On the other hand, consuming fish and its byproducts exposes individuals to *S. aureus* enterotoxins, which can result in gastroenteritis (Novotny *et al.,* 2004). The health of the general people is threatened by the heat-resistant *S. aureus* enterotoxins (Obaidat *et al.,* 2015). *S. xylosus* has just been identified as the primary fish pathogen, despite the fact that the majority of research on *S. aureus* infections in humans has focused on fish consumption. The freshly identified bacterium can impair fish immunity, cause exophthalmos, and cause fish mortality. In many countries, raw fish is consumed, which increases the risk of disease transmission to humans (Oh *et al.,* 2019). Toxic shock syndrome (TSS), which acts as a super antigen to activate polyclonal T lymphocytes in peripheral circulation and reach the bloodstream, is a condition that may result from the bacterial TSST-1 toxin in *S. aureus* skin infections (Pomputius *et al.,* 2023).

4.2.4. Listeria monocytogenes

Listeria monocytogenes was the type of bacteria that was most abundant in fish and fisheries products in 2016, according to the European Food Safety Authority (EFSA). This pathogen has been confirmed to exist in fish products, according to Gawade *et al.* (2010). It is a Gram-positive bacterium that can survive in both fresh and salty environments and can resist a variety of temperatures, including those found in a refrigerator. This bacterium, which was initially discovered to infect people through food, is now a public health concern since it has been associated to septicemia, meningitis, gastroenteritis, pneumonia, and abortion. Because *Listeria monocytogenes* is an indigenous flora of surface water and can be found on fish skin, mucus/mucosa, intestines, stomachs, and gills of contaminated fish, contact with the fish skin and faecal contents is the source of sickness transmission (Jami *et al.,* 2014). High risk groups for human listeriosis include pregnant women, the elderly, and people with immune system or chronic medical conditions (Lassen *et al.,* 2016).

4.2.5. Clostridium **species**

Serious food-related illnesses brought on by the anaerobic rod-shaped spore-forming bacteria *Clostridium perfringens* and *Clostridium botulinum* can be contracted by eating both fresh and tinned fish. The bacteria are widespread in soils, aquatic sediments, and uncultivated anaerobic habitats, according to Sabry *et al.* (2016). Humans get gastroenteritis as a result of enterotoxins (CPE), specifically kinds A, C, and D produced by *Clostridium perfringens* from the cpe gene (Sabry *et al.,* 2016). According to Uzal *et al.* (2014), the chemicals could possibly damage organs like the brain by entering the bloodstream through the gut. On the other hand, according to Espelund and Klaveness (2014), *Clostridium botulinum* spores can persist for many years in freshwater and marine sediments as well as in the stomachs of healthy fish. By preventing synaptic vesicles at neuromuscular junctions from releasing acetylcholine, botulinum toxins (types A–H) produced by the bacteria, according to Barash and Arnon (2014), cause flaccid paralysis. The letters A, B, E, and F are toxic to people. Fish intestines can occasionally produce botulinum neurotoxin. The botulinum toxins have a low thermal stability and require high temperatures to become inebriated. According to Rasetti-Escargueil *et al.* (2019), the symptoms of botulism danger typically appear early and include dysphagia, diarrhoea, vomiting, bloating, lightheadedness, and constipation.

4.2.6. Campylobacter

Campylobacter is a characteristic zoonotic bacterium that can be found in the digestive tract of many animals, according to Facciolà *et al.* (2017). Instead of fish products that humans eat, unclean water and a food handler's hands are the main sources of campylobacteriosis in humans. This genus contains important enteropathogens including *Campylobacter jejuni* and *C. coli*. By employing bacterial motility, intestinal cell adhesion and invasion, altering intracellular signaling, inducing cell death, evading the host immune system, and getting iron for their growth and survival, the bacteria that cause campylobacteriosis appear as enteritis (Epps *et al.*, 2013).

4.2.7. Plesiomonas shigelloides

It has been discovered as a water-borne pathogen in freshwater fish (Nakajima *et al.*, 1991).

4.2.8. Legionella pneumophila

The agent that causes legionnaires' disease/pneumonia, *Legionella pneumophila*, was discovered in a patient who worked at a fish market. It can spread by aerosols and water (Novotny *et al.*, 2004).

4.2.9. Yersinia ruckeri

Salmonids, eels, goldfish, sole, sturgeon, trout, carps, and turbot are all reservoirs for yersiniosis, also known as red mouth disease. Blood stains in the eye and exophthalmos are typical presentations of the illness. The bacterium is present in fish populations all over Europe, North and South America, Australia, and New Zealand, according to Carson *et al.* (2019).

4.3. Zoonotic bacterial pathogens of fish transmitted by more than one route (contact and ingestion):

4.3.1. Hafniaceae

Gram-negative, moveable, rod-shaped bacteria belong to the Order Enterbacteriales. The three genera that make up this family, according to Adeolu *et al.* (2016), are *Hafnia*, *Edwardsiella*, and *Obesumbacterium*. *Edwardsiella* are particularly harmful to aquatic creatures since they can lead to edwardsiellosis, a systemic disease that affects fish, according to Miniero Davies *et al.* (2018). In case of high ambient temperatures associated with higher levels of organic debris, the bacteria become more toxic to fish. Up until the year 1980, *Edwardsiella* only had one species, *E. tarda*. Recently, however (Bujan *et al.*, 2018), two additional species, *E. piscicida* and *E. anguillarum* (*E. tarda*), have been added to the list of recognized species. According to Kerie *et al.* (2019), *E. tarda* is believed to be the primary cause of infections in humans while other species, such as *E. hoshnae*, are pathogenic to fish. Compared to *E. piscicida*, *E. tarda* has proven to be less harmful in aquaculture, according to the updated classification (Leung *et al.*, 2019). Currently, the *Edwardsiella* infection can spread to more than 20 different fish species in Asia and Europe. As behavioural markers, fish with the illness may display erratic swimming, lateral movement, and swirling in the water column. Human gastroenteritis is brought on by the opportunistic bacterium *E. tarda*, but it can also lead to other types of edwardsiellosis outside of the digestive tract, including liver and wound infections, cholecystitis, peritonitis, meningitis, myonecrosis, osteomyelitis, sepsis, and bacteremia (Kerie *et al.*, 2019). *E. tarda* infections in humans are uncommon (5%), although they can be lethal in some cases. The problems caused by *E. tarda* are more likely to affect those with compromised immune systems or underlying conditions such diabetes and hepatobiliary disease (Wimalasena *et al.*, 2018). People can contract edwardsiellosis by swimming in contaminated water, eating raw fish, coming into contact with fish, or having a compromised immune system. Bacterial adherence to cells, the usage of hemolysin, and secretion systems are other methods by which bacteria invade and infect human cells. *Edwardsiella* grows in phagocytes before invading neighbouring cells. Due to their major contribution to the emergence of antibiotic resistance, the bacteria should receive increased focus in the coming decades (Leung *et al.*, 2019).

4.3.2. Enterobacteriaceae

The *Enterobacteriaceae* family of fish microorganisms may be harmful to humans. According to Oliviera *et al.* (2017), a number of human illnesses are caused by members of this family of organisms. *Salmonella*, *Klebsiella*, and *Escherichia coli* are members of this family of bacteria, which is frequently referred to as the zoonotic agents of fish (Boylan, 2011). These Gram-negative bacteria have been discovered in fish digestive systems and aquatic settings, according to Oliviera *et al.* (2017). Open wounds, contact with fish, or scrapes that result in infection and inflammation at the bacterium's entry point as well as systemic illnesses are the most frequent sources of these bacteria in people. However, some members of this bacterial family have been linked to human disorders through dietary sources, such as eating imported dried fish that has been linked to *S. typhimurium* infections (Bonyadian *et al.*, 2014). The presence of *E. coli* strains in many fish species indicates that fish are a new vector for this bacterium in water sources (Hansen *et al.*, 2008). Fish can carry different *E. coli* strains to other water sources and keep them as flora, according to Guillen and Wrast (2010). *E. coli* is frequently isolated from fish's digestive tract despite not being a typical member of the fish's microbiome. In polluted conditions, *E. coli* has also been seen penetrating into the gill, kidney, muscle, and bladder of fish (Ziarati *et al.*, 2022). These illnesses are influenced by the seasons, fish interactions, contaminated habitats, and an individual's immune system. One of the agents responsible for zoonotic infections spread by fish or other aquatic animals is *Escherichia coli*. However, non-pathogenic strains frequently only succeed in doing so when they pass the intestinal barrier and reach other organs such the urinary tract or peritoneum (Haile and Getahun, 2018). Non-pathogenic strains can still create toxins in fish that can cause diarrhoea or food poisoning. Several *E. coli* strains that have been discovered from different countries are zoonotic agents, according to reports (Cardozo *et al.*, 2018).

Through fish, aquaculture products, and water, *Salmonella enterica* subspecies enterica is effective in the development of intestinal illnesses. *Salmonella* is an uncommon fish bacterium that is impacted by the aquatic environment and water quality. When fish have bacteria in their stomachs or on the surface of their skin, they can develop into asymptomatic hosts for those germs. Fish and water samples from the following species have been reported to have Salmonella isolates: *S. eastbourne*, *S.*

give, S. colindale, S. bredeney, S. poona, S. schwarzengrund, and *S. llandoff*. Eating infected fish can cause human salmonellosis, with *S. typhimurium* and *S. enteritidis* being the most common infections. Their pathogenicity is determined by a variety of factors, including secretory systems, proteins, intra-phagocyte proliferation, intestinal lumen transfer, and tissue viability (Ziarati *et al.*, 2022). According to Traoré *et al.* (2015), *Salmonella*'s capacity to survive in fish digestion and manifest itself in faeces are significant contributors to the spread of bacteria and environmental pollution. When seafood is contaminated with salmonella, it can cause bacteremia, fever, gastroenteritis, and stomachaches. Salmonella can also spread from smoked fish to human skin, gills, and intestines (Bibi *et al.,* 2015). Sepsis, stomach ache, diarrhoea, and vomiting are a few of the clinical effects of salmonella infection (Lehane and Rawlin, 2000). In untreated water samples from dunes, seas, dams, prawns, and freshwater fish, *Klebsiella pneumoniae* and *K. oxytoca* have been identified (Gopi *et al.,* 2016). In cases of farmed fish in India with clinical hemorrhagic problems close to the tail as well as vacuolation and necrosis of hepatocytes, *K. pneumoniae* has been isolated and identified. There are worries over the spread of *Klebsiella* spp. (*Klebsiella pneumoniae* complex) to humans due to their zoonotic nature and multi-drug resistance (Das *et al.*, 2018). It was discovered that the infectious process was caused by poor food processor hygiene when *Klebsiella* was isolated from the skin lesions of a carp, an ornamental fish (Oliveira *et al.*, 2014). The direct consequences of the endotoxin and abnormal immune reactions have an impact on the symptoms of fish that have been infected with *Klebsiella* as well (Diana and Manjulatha, 2012).

<u>4.3.3. Aeromonadaceae</u>

Another Gram-negative pathogen infects fish, and until environmental stress and weakening, infections are asymptomatic. Fish can be infected by both *Aeromonas* and *Vibrio*, however *Aeromonas* is more common in freshwater fish, but *Vibrio* species can also be found in brackish, estuarine, and marine waters. Both bacteria have the potential to be harmful to human health (Boylan, 2011). According to Abd-El-Malek (2017), fish are a crucial part in *Aeromonas* transfer to humans. *A. hydrophila* is the most prevalent pathogen among the species identified to have zoonotic potential, followed by *A. jandaei, A. salmonidae, A. sorbia, A. caviae,* and *A. veroni* (Noga, 2010). In recent decade, several fish infections, like *A. jandaei* and *A. veroni*, can make fish exhibit the same symptoms as *A. hydrophila*. As a secondary infection, *A. hydrophila* also causes opportunistic illness in vulnerable fish. Organs include the gills, liver, stomach, kidney, and spleen have had histopathological alterations (AlYahya *et al.* 2018). Petechiae on the skin and fins, skin ulcers, arrhythmias, anorexia, exophthalmia, and abdominal enlargement are a few clinical signs of fish with *Aeromonas* infection (Agnew and Barnes, 2007). Additionally, although it is uncommon in humans, the *Aeromonas* species can infect people through their stomachs or by ingesting them. Muscle necrosis, cellulitis, and septicemia are a few clinical impacts on the people (Volpe *et al.*, 2019). Edoema to swelling at the site of infection are among the disease's clinical symptoms in humans (Boylan, 2011). In addition, sepsis, bacteremia, urinary tract infections, lung infections, gastroenteritis, and diarrhoea can all be brought on by *Aeromonas* in people. According to Odeyemi and Ahmad (2017), the multi-antibiotic resistance of *Aeromonas* is a sign of a developing general health issue in both people and aquatic animals.

5. *Diagnosis*

Fish samples are immediately transported after aseptic collection to laboratories for diagnostic purposes (Lowry and Smith, 2007). The majority of bacterial infections may be cultured mainly from a fish's caudal kidney (Ho *et al.,* 2006). Checking the shape of bacterial colonies produced on an agar plate is important, as well as testing the bacterial motility, staining affinity, biochemical reactions, and occasionally immunological characteristics. All tests are run on colonies of 24 to 48 hours old (Zrnčić and Radosavljević, 2017). One straightforward test for general medical bacteriology is the Gram staining where the majority of fish pathogens are Gram negative (Midtlyng *et al.,* 2000). The O-F test is used to identify whether a bacteria is metabolizing glucose and, if so, whether it does so by fermentation (anaerobic settings) or oxidation (aerobic conditions). Furthermore, the chemical 0/129 is used in vibriostat testing because it prevents the majority of the bacteria in the genus *Vibrio* from growing (Zrnčić and Radosavljević, 2017). Flowcharts with descriptions of the biochemical tests are used to determine the bacterial species with certainty. There are a number of commercially available diagnostic kits, such as the BBL™ and Crystal™ Identification Systems (an identification method using fluorogenic and chromogenic reagents) or the Analytical Profile Index (API) system (is a manual microorganism identification to species level based on substantial databases) (Plumb and Hanson, 2010).

Serodiagnosis allowed for quick diagnosis to be made from infected fish tissues even on the fish farm before the present focus in molecular approaches. When utilized in the fluorescent antibody test, whole cell assay, antibody-coated latex particles (sometimes known as a latex test), Geck test or the immuno-India ink approach and ELISA assay (Saeed and Plumb, 1987). Polyclonal antisera were effective at detecting the presence of pathogens but the chance of misidentifcation became increased than the specific monoclonal antibodies (Goerlich *et al.*, 1984). In addition, according to Austin and Austin (2016), the diagnosis of diseases in aquatic animals can also be done with the help of nucleic acid amplification using multiplex PCR, quantitative or real-time PCR, reverse transcription PCR (RT-PCR), PCR (single or nested test), terminal-restriction fragment length polymorphism (RFLP), PCR-RFLP, multiplex PCR, real-time recombinase polymerase amplification. All of these approaches had incredibly high levels of sensitivity, detecting cell counts that were far lower than those connected to the emergence of clinical illness. In order to amplify a specific region of DNA, short oligonucleotide primers are created that will hybridize to both ends of the target region on opposing DNA strands (Midtlyng *et al.*, 2000 and Puah *et al.,* 2018).

6. Prevention and Control Measures

Like other subspecialties of veterinary medicine, aquatic medicine emphasizes the idea that prevention is preferable to treatment. To prevent the introduction and spread of a pathogen in an animal population, it is essential to develop a workable biosecurity plan for aquaculture operations and communicate biosecurity concepts to clients (Lowry and Smith, 2007). Controlling fish illness is difficult because environmental factors have an impact on how effectively farmed fish are produced. Environmental variables have a significant impact on fish health, and the majority of fish diseases are brought on by the deterioration of the aquatic environment.

Therefore, multidisciplinary approaches involving the characteristics of potentially fish pathogenic microorganisms, aspects of fish biology, as well as a better understanding of the environmental factors, will enable the application of appropriate measures to prevent and control the diseases limiting fish production (Toranzo *et al.,* 2005). Because aquatic animal zoonotic infections are underreported, risk estimates are difficult. To reduce the risk of topically acquired infection, those with open cuts, scrapes, or sores on their skin should avoid direct contact with potentially contaminated fresh or salt water (Haenen *et al.,* 2013). People with compromised immune systems should avoid handling fish or caring for fish aquariums. They should put on heavy, waterproof gloves when handling or processing fish or cleaning indoor aquariums or fish tanks. Everyone should thoroughly wash their hands with soap and water after handling or touching fish. It is also essential to guarantee that fish tanks and swimming pools are appropriately and frequently chlorinated in order to get rid of any dangerous microorganisms (Evans *et al.,* 2009). Veterinarians can provide patients with a variety of recommendations on how to reduce the possibility of zoonotic diseases spreading to populations of established aquatic animals. To separate new fish from existing populations, use tanks or a quarantine area. According to Jahnck and Schwar (2002), this contributes in limiting the spread of zoonotic illnesses among fish populations. Normally, new fish should be quarantined for 30 to 45 days in order to observe their behaviour, gauge how they respond to food, and look for any clinical signs. While persistent infections with pathogens like *Mycobacterium* spp. may not always be apparent, the bulk of active pathogens are typically present at this time in newly acquired fish. In order to prevent contamination of existing fish populations, the quarantine area or facility should be regarded as a separate area and furnished with nets, feed, water supply, and tank-cleaning equipment intended for use only there (Lowry and Smith, 2007).

CONCLUSION AND FUTURE PROSPECTS

Zoonotic agents have grown to be a serious worry for the fishing and worldwide health industries as a result of rising seafood demand and consumption. There is currently a lack of information regarding the biodiversity, ecology, occurrence, and distribution of pathogens produced from fish. The motivation behind the current review project was the dearth of understanding on the presence and prevalence of zoonotic variables. More research is needed on the various hosts, geographic distribution, and effects of seasonality on infection prevalence. In order to improve our appreciation of the occurrence of diseases in their habitats as well as our awareness of the food business, biosecurity, and medical practices, a stronger understanding of the morphology of pathogens is also required. Innovative molecular diagnostic methods must be created in order to find zoonotic illnesses, particularly those that originate from fish. This will make it simple and affordable to monitor zoonotic infections in marine, freshwater, and ornamental species of fish. Since fish is a vital food of low cost, it has become simpler for people to catch aquatic diseases due to the presence of some probable zoonotic viruses. Because of this, it is essential for public health to teach people about control and preventative measures, which should be viewed as a fundamental component of human civilizations.

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