

# Zoonotic Fish-Borne Infections in the Context of Sea Travel: Prevention and Control Measures

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## Abstract

Zoonotic diseases associated with sea travel pose a serious threat to public health due to increased international traffic and the movement of aquatic animals. These diseases, which are transmitted from animals to humans, are particularly complex because of the diversity of transmission routes and the absence of symptoms in many aquatic organisms. Risk factors include ecological changes, human demographic and behavioral characteristics, and the inefficiency of public health systems. Climate change and environmental degradation may lead to the emergence of new diseases in marine plants and animals. To prevent and control infectious diseases, multiple monitoring systems and control strategies have been designed by the WHO and WOA. Public education and raising awareness among the medical community are key factors in the prevention and control of these diseases. Additionally, hand hygiene and the use of low-risk methods for greetings on cruise ships are recommended. Identifying transmission routes, assessing risks, and developing preventive strategies with a One Health approach are essential measures to combat these threats. However, research gaps and the lack of epidemiological data hinder the development of effective policies. The future of this field requires scientific investment and international collaboration to enhance preparedness against zoonotic diseases related to sea travel.

**Keywords:** Zoonoses, Public Health, Disease Transmission, Climate Change, Prevention and Control.

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## Introduction

The spread of infectious diseases worldwide has been a serious threat to public health and national economies for centuries. One of the undeniable factors contributing to the spread of disease has been maritime transport <sup>1</sup>. International travel and trade are recognized as factors that increase the risk of infectious disease transmission across countries. There is no international surveillance system for infectious diseases aboard ships <sup>2</sup>. An infectious disease that is transmitted during sea travel may go through its incubation period in individuals disembarking from cruise ships and result in an outbreak in the communities where travelers reside, especially in confined environments like nursing homes. Therefore, the health importance of diseases occurring on cruise ships is not only related to the widespread outbreaks on the ships themselves but also to the global transmission of the disease to communities <sup>3</sup>. A zoonotic disease is defined as

an infection or disease that can naturally be transmitted from vertebrate animals to humans or from humans to vertebrate animals. Over 60% of human pathogens are zoonotic in origin. This group includes a wide range of bacteria, viruses, fungi, protozoa, parasites, and other pathogens. Factors such as climate change, urbanization, animal migration and trade, travel and tourism, vector biology, human factors, and natural factors have a significant impact on the emergence, re-emergence, spread, and patterns of zoonotic diseases. Over time, the number of emerging and re-emerging zoonotic diseases has been increasing <sup>4</sup>. Potential risk factors for the transmission of zoonotic diseases from fish to humans include the consumption of raw or undercooked contaminated fish, contact with contaminated water or infected fish. Therefore, conducting thorough epidemiological surveillance of zoonotic bacteria and

parasites in fish and evaluating their public health significance is essential <sup>5</sup>. Among the bacteria generally recognized as agents of zoonotic diseases transmitted from fish, only species of *Mycobacterium* (*Mycobacterium* spp.), *Streptococcus iniae*, *Clostridium botulinum*, and *Vibrio vulnificus* have been definitively and documented as zoonotic agents in the strict sense <sup>6</sup>. Many marine and freshwater fish are recognized as sources of zoonotic parasitic diseases of medical importance, including trematodiasis, cestodiasis, and nematodiasis. Some of these infections are highly pathogenic and primarily transmitted to humans through the consumption of raw or undercooked fish <sup>7</sup>. Despite the high importance of infectious diseases in sea travel, there are numerous research gaps that require further investigation, such as the lack of comprehensive surveillance systems for monitoring infectious diseases aboard ships, the lack of comprehensive studies on the role of sea travel in the transmission of zoonotic diseases, the insufficient investigation of the impact of climate change on the prevalence of marine diseases, the lack of epidemiological data on the prevalence of infectious diseases during sea travel, the absence of standardized strategies for managing infectious diseases aboard ships, and the need for the development of rapid diagnostic methods applicable in marine environments. The aim of this review article is to analyze and summarize the existing studies on the transmission of zoonotic diseases from fish to humans during sea travel. This research examines the various factors that may contribute to the outbreak of zoonotic diseases in these environments and also identifies existing research gaps in this field. This article also attempts to propose effective protocols and health systems for managing and preventing these diseases aboard ships and during sea travel.

### Zoonotic Diseases Related to Sea Travel

In recent years, the volume of international traffic has increased significantly, which has substantially raised the risk of infectious disease transmission <sup>8</sup>. A wide range of infectious diseases can lead to outbreaks aboard ships, which in turn have significant health and economic consequences <sup>9</sup>. The term "zoonosis" refers to a disease that humans can acquire from domesticated or wild animals. Zoonotic diseases require special attention due to the widespread movement of live aquatic animals and their products, as well as the global expansion of aquaculture. Due to the diversity of transmission routes and the fact that many zoonotic diseases in aquatic organisms do not cause obvious symptoms, the pathogenic interactions between aquatic species and humans are complex and multifaceted <sup>10</sup>. Zoonoses

(diseases transmitted from animals to humans) are one of the five main pillars of the "One Health" framework. The One Health concept aims to prevent and control zoonotic diseases through effective collaboration and communication among stakeholders in human, animal, and environmental health sectors. Estimates suggest that around 60% of all emerging infectious diseases (EIDs) are of zoonotic origin, and nearly 70% of them originate from wildlife. Evidence shows that incidents related to emerging zoonotic diseases originating from wildlife have significantly increased over time <sup>11</sup>. The interaction of pathogens between humans and aquatic species is highly complex due to the multiple transmission routes and the fact that many zoonotic pathogens in aquatic organisms do not cause disease. Therefore, seemingly healthy fish can act as asymptomatic carriers of pathogens that are transmitted to humans. Additionally, some microorganisms that are usually harmless in aquatic species may pose a zoonotic risk to humans. The complexity in diagnosing diseases in fish arises when clinical signs of disease in aquatic species often do not correlate well with the clinical signs observed in infected humans <sup>12</sup>. Zoonotic infections related to aquatic species can be divided into two main categories:

- a) Local infections resulting from direct contact with aquatic animals or their products,
- b) Foodborne infections resulting from the consumption of raw or undercooked aquatic products.

Pathogens may be native to aquatic environments or may enter these ecosystems due to environmental contamination, such as farms located in polluted areas, the use of manure as fertilizer, and the introduction of human wastewater, agricultural runoff, or wildlife waste into water sources, all of which are potential sources of contamination. Pathogens like *Salmonella*, *Shigella*, *Escherichia coli*, *Yersinia*, *Brucella*, and *Edwardsiella* are well-known factors in this context. Pathogenic or potentially pathogenic bacteria associated with fish and shellfish include *Mycobacteria*, *Streptococcus iniae*, *Vibrio vulnificus*, various *Vibrio* species, *Aeromonas*, *Salmonella* spp., and others. From a microbiological perspective, fish and their products are considered high-risk food groups. Among these, *Clostridium botulinum* type E and *Vibrio parahaemolyticus* are the most important pathogenic bacteria associated with fish. Other potentially pathogenic bacteria reported in fish and shellfish include *Clostridium perfringens*, various *Staphylococcus* species, *Salmonella*, *Shigella*, *Vibrio cholerae*, and other *Vibrio* species <sup>13</sup>. The primary transmission routes for zoonotic infections include the consumption of undercooked or raw fish, contact with contaminated water, and direct contact through open

wounds. Zoonotic bacteria such as *Vibrio*, *Mycobacterium*, *Streptococcus*, and *Aeromonas* not only pose serious health risks but also have significant economic impacts on the aquaculture industry. Parasitic infections, including those caused by *Anisakis* and liver flukes, often occur as a result of consuming raw or undercooked fish and can lead to gastrointestinal and systemic diseases in humans. Viruses like norovirus and hepatitis A virus are primarily transmitted through contaminated seafood. Although less common, fungal infections may also be transmitted to humans through direct contact with infected fish or its surrounding environment <sup>14</sup>. The World Health Organization (WHO) published a list of important parasites transmitted through meat and fish in 2002. These parasites include *Anisakis* spp., *Capillaria philippinensis*, *Clonorchis sinensis*, *Diphyllobothrium* spp., *Echinococcus* spp., *Fasciola* spp., *Fasciolopsis buski*, *Gnathostoma* spp., *Opisthorchis* spp., *Sarcocystis* spp., *Spirometra* spp., *Taenia* spp., *Toxoplasma gondii*, *Trichinella* spp., and blood flukes. These parasites can be transmitted to humans through the consumption of contaminated animal and aquatic products and can cause a range of gastrointestinal, liver, neurological, and systemic diseases <sup>15</sup>.

### Transmission Routes of Zoonotic Diseases from Fish to Humans During Sea Travel

Globally, the highest incidence of zoonotic diseases caused by aquatic animals occurs in coastal areas, where seafood consumption is more common. However, continuous advances in transportation, technology, and food processing have made it possible to distribute fresh aquatic animals globally. Therefore, the risk of parasitic infections from seafood is not limited to coastal populations <sup>16</sup>. Today, over 40 parasitic species across various groups, including protozoa, trematodes, cestodes, nematodes, and acanthocephalans, have been identified in fish, causing diseases in humans. Human infection typically occurs after consuming contaminated edible tissues containing the larvae of these parasites. Therefore, the relationship between disease transmission and fish processing methods, cooking, and epidemiology is crucial. Fish consumption, cooking methods, food processing, or eating habits and hygiene levels are factors that affect the occurrence of these parasites <sup>17</sup>. Zoonotic parasitic diseases are transmitted to humans through the ingestion of resistant stages and transmission forms in the environment (such as spores, cysts, oocysts, eggs, larvae, or encapsulated tissue stages) or by consuming raw or undercooked fish containing infective stages. Humans can serve as the definitive host, intermediate host, paratenic host, or accidental host for these parasites. Although the

transmission stages of some of these diseases can be directly transferred (e.g., through contact between humans and animals or with contaminated feces, soil, or vegetation), transmission can also occur via contaminated water and food <sup>18</sup>. Larvae from the genus *Pseudoterranova*, when consuming raw or undercooked fish, can pose a threat to human health. These larvae cause pseudoterranovosis, a zoonotic disease transmitted by fish, with varying pathogenicity depending on the species involved. Therefore, accurately identifying the causative species is essential for understanding this zoonosis <sup>19</sup>. Diseases such as salmonellosis and botulism are associated with food handling and storage practices, as well as traditional eating habits like consuming raw, undercooked, or fermented foods <sup>20</sup>. *Mycobacteria* are a group of slow-growing, aerobic, non-motile, acid- and alcohol-resistant bacilli that can cause prominent granulomatous nodules and extensive damage in fish. Contact between human skin wounds or abrasions with sources infected with *mycobacteria* may lead to various forms of cutaneous tuberculosis in humans. The clinical manifestation of this disease often appears as relatively painless nodules accompanied by skin ulcers and scarring <sup>21</sup>.

### Common Zoonotic Diseases in Marine Fish

With population growth, the need for fish consumption has increased. Many fish species serve as hosts for parasites that are shared between humans and fish. Anisakiasis is considered one of the significant zoonotic diseases shared between humans and fish. The causative agent of this disease is the larval stage of nematodes from the Anisakidae family, including *Pseudoterranova* and *Anisakis* <sup>22</sup>. A few years ago, infections with *Anisakis* were nearly unknown. Since the first observation of this parasite in the Netherlands in 1960, numerous cases of gastrointestinal infections caused by this zoonotic disease, caused by this nematode, have been reported in countries where consuming raw or undercooked fish (such as vinegar- or salt-cured fish) is common. Japan alone accounts for 90% of the total reported cases of anisakiasis in scientific literature, due to the widespread use of raw fish in traditional Japanese cuisine, such as sushi and sashimi. However, cases have also been reported from Europe, North and South America, and Asia. In Italy, this zoonotic disease is rare and primarily transmitted through the consumption of cured anchovy fish in coastal areas or trendy foods (like sushi and sashimi) in non-coastal regions. After consumption, the parasite may cause an acute disease with severe abdominal pain, and many patients are diagnosed only after surgical examination. Since conservative medical treatment for acute anisakiasis

relies on the endoscopic removal of the nematode from the gastrointestinal wall (if performed within 12 hours of consuming contaminated fish), considering this parasite in emergency departments is crucial <sup>23</sup>. Anisakiasis is a disease caused by the nematode *Anisakis*, which occurs in humans due to consuming raw and undercooked fish infected with larvae. Given that this disease is zoonotic, health recommendations should be provided to individuals who have a strong preference for eating raw, especially various types of seafood. *Anisakis* infection has been reported in Iran since 1970. Considering the high infection rate of up to 97% in some fish species studied, further attention to this parasite in food hygiene is needed <sup>24</sup>. Freshwater and marine ecosystems provide suitable habitats for parasitic nematodes from the genus *Contraecum* (family: *Anisakidae*) to complete their complex life cycles <sup>25</sup>. Anchovies, sardines, and Mediterranean horse mackerels have low to moderate prevalence and intensity of larval *Anisakidae* infestation in both their viscera and muscles. Additionally, the average intensity of infestation has been reported as low <sup>26</sup>. Diphyllbothriosis, a zoonotic disease transmitted through fish in South America, is primarily caused by the broad fish tapeworm *Adenocephalus pacificus* (Nybelin, 1931). This parasite is of considerable public health importance due to its impact on public health in fishery resources. A new species of diphyllbothriid, *Diphyllbothrium sprakeri*, has recently been identified in sea lions along the Pacific coast, although marine fish as its intermediate host remain unidentified <sup>27</sup>. The causative agent of mycobacteriosis is various species from the genus *Mycobacterium*. Mycobacteriosis is a chronic, progressive disease that may affect all tissues of the fish. External signs in fish include loss of scales, skin ulcers, skeletal abnormalities, etc. Internal signs of infection include liver, spleen, and kidney enlargement and the presence of white nodules in internal organs. Mycobacteriosis is a zoonotic occupational disease, and those working with fish are at higher risk <sup>28</sup>. Mycobacteriosis in fish, also known as fish tuberculosis, is one of the chronic granulomatous diseases in fish, characterized by excessive weight loss, loss of body color, superficial or deep skin ulcers, and white nodules in internal organs. This systemic granulomatous disease occurs in aquarium and cultured fish, especially those kept under poor conditions. It is transmissible to humans and is commonly referred to as "fish tank granuloma" or "swimming pool granuloma," usually manifesting as a skin disease, including granulomatous inflammation or nodular or diffuse granuloma of the skin, subcutaneous tissue, and tendon sheaths of fingers and hands. Although all freshwater and marine ornamental fish are susceptible

to this disease, the families Anabantidae (betta and gouramis), Carassidae (tetras), and Cyprinidae (barbs, koi, and goldfish) show higher sensitivity. The common species of *Mycobacterium* that cause fish tuberculosis include: *M. marinum*, *M. chelonae*, *M. fortuitum*, and *M. neoaurum*. Various species of *Mycobacterium* cause diseases in different animals, some of which also lead to significant human diseases <sup>29</sup>. *Streptococcus iniae* and *Lactococcus garvieae* are bacteria causing streptococcosis and lactococcosis in fish, which can be transmitted to humans through contact or consumption of infected fish. These pathogens have become increasingly prevalent in fish farms in Iran in recent years <sup>30</sup>. *Aeromonas hydrophila* is a Gram-negative, motile bacterium that is an opportunistic pathogen and zoonosis in warm-water fish. The high mortality rate in fish, economic losses, and bacterial resistance are major factors driving the development of new methods such as vaccination against *Aeromonas hydrophila* <sup>31</sup>. *Aeromonas hydrophila* is a Gram-negative bacterium that causes ulcerative wounds and septicemia in aquatic animals and diarrhea in humans. *Streptococcus iniae*, a Gram-positive bacterium, causes pathogenic symptoms such as protruding eyes, superficial wounds on fins and gills of fish, and skin wounds in human hands and feet. *Edwardsiella tarda*, a Gram-negative bacterium from the Enterobacteriaceae family, causes hemorrhagic septicemia in fish and gastroenteritis in humans <sup>32</sup>. *Erysipelothrix* species, including *E. rhusiopathiae*, are zoonotic pathogens that can cause disease and death in mammals, fish, reptiles, birds, and humans <sup>33</sup>.

### **Risk Factors in the Transmission of Fish Zoonotic Diseases During Sea Travel**

Disease is a natural part of all ecosystems; however, in some cases, the disruption of the balance between the host, pathogen, and environment can lead to outbreaks in both wild and cultured populations. In marine systems, interactions between hosts and microorganisms are less understood than those in terrestrial systems. Biological and physical changes in the world's oceans, along with other impacts from human activities, are likely to increase the occurrence of opportunistic diseases in marine environments <sup>34</sup>. The long-term consequences of climate change and potential environmental degradation are likely to include the emergence of new diseases in marine plants and animals. These emerging diseases, in turn, may have epidemic potential, zoonotic consequences, and complex pathogenesis, with factors such as pollution load from human activities, genetic factors, and immune disruptions also playing a role <sup>35</sup>. Multiple factors can contribute to the emergence of infectious diseases, including ecological

changes (such as those resulting from economic development, agricultural land use, or marine activities), human demographic and behavioral characteristics, international travel and exchanges, technology and industry, microbial adaptation or changes, and inefficiencies or disruptions in public health systems <sup>36</sup>. Environmental factors such as salinity, temperature, nutrients, and light affect the survival of pathogens and, in some cases, their proliferation <sup>37</sup>. It is commonly assumed that as climate change intensifies, natural systems will face an increased risk of infectious disease outbreaks <sup>38</sup>.

### Preventive Measures and Control of Fish Zoonotic Diseases During Sea Travel

Various monitoring systems and control strategies have been designed and implemented within the frameworks of WHO and the World Organisation for Animal Health (WOAH) to prevent and control infectious diseases and to raise public awareness regarding the health risks associated with zoonotic diseases <sup>39</sup>. Analyzing travel volume provides important information that can be used for effectively targeting public health interventions and directing resources and health efforts at local, regional, and national levels <sup>40</sup>. Public education and raising awareness among the medical community about this largely neglected tropical/subtropical disease is a key factor in its prevention and control <sup>41</sup>. A firm handshake is a common way of greeting, but fingers and palms can transfer bacteria and viruses. Hand hygiene plays an important role in preventing the spread of infectious diseases; however, proper hand washing is time-consuming and may not always be adequately performed. A ban on handshakes in healthcare settings has been suggested, but in such cases, a safer alternative form of greeting should be used. Cruise ships, in particular, are vulnerable to infectious diseases transmitted from person to person. The fist bump, which is common in some subcultures, is increasingly becoming the preferred greeting method on smaller ships. To further reduce contact, a modified form of the fist bump known as the "sea bump" or "cruise tap" is recommended, where only two fingertips briefly touch each other <sup>42</sup>. In addition to recommendations regarding preventive measures and vaccination, counseling on the use of antiviral medications may also be of interest to some travelers <sup>43</sup>.

### Conclusion

With the expansion of sea travel and increased human contact with aquatic environments and marine organisms, the risk of zoonotic disease transmission has also increased. These diseases, often transmitted through direct contact with infected marine animals, consumption of

contaminated seafood, or contact with polluted water, can pose a public health risk to passengers, ship crew members, and coastal residents. Identifying transmission routes, risk assessment, public education, and developing preventive strategies with a One Health approach are essential actions to address these emerging threats. However, several research gaps, including a lack of epidemiological data, inadequate surveillance systems, and a lack of interdisciplinary studies, hinder the development of effective policies. Therefore, the future of this field requires scientific investment and international cooperation to enhance preparedness for zoonotic diseases related to sea travel.

#### Highlights

##### What Is Already Known?

Zoonotic fish-borne infections pose significant health risks to travelers engaging in sea activities. These infections, transmitted through contaminated fish or water, can lead to severe illnesses. Preventive measures include proper cooking, avoiding raw fish, and ensuring safe water sources. Awareness and education are crucial for effective control and prevention strategies.

##### What Does This Study Add?

It can provide essential insights into the risks associated with consuming fish during sea travel. It highlights the importance of understanding transmission routes, preventive strategies, and control measures to safeguard travelers' health and promote safe seafood consumption practices.

#### Authors' Contributions

The resource and writing-original draft preparation were carried out by MRH. The writing review and editing were performed by SB and SKA. The supervision was done by SKA. The whole manuscript was read and approved by all authors.

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