Zoonotic Parasitic Infestations in Fish and their Impact on Public Health and Aquatic Ecosystems

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ABSTRACT

Parasites represent a major threat to wild and farmed fish stocks, resulting in significant economic losses in fisheries and aquaculture globally. In addition, some fish parasites have a zoonotic potential, posing risks to human health through consumption of infected raw or undercooked fish. These primarily include helminth parasites, such as nematodes, cestodes, trematodes and acanthocephalans. Anisakid nematodes are among the most common fish-borne zoonotic parasites, causing human infection via consumption of third stage larvae in raw or undercooked fish hosts. An additional nematode, Capillaria philippinensis, may also be transmitted by ingesting infected fish, although freshwater fish are the typical second intermediate hosts. Some major groups of cestodes, including diphyllobothriid tapeworms, use fish as secondary intermediate hosts and can infect humans that eat plerocercoid larvae in raw or poorly cooked fish. Digenean trematodes also utilize fish as secondary intermediate hosts, with some species occasionally infecting human definitive hosts if metacercariae in raw or pickled fish are ingested. While clinical manifestations vary widely, they may include allergic reactions, gastrointestinal disturbances, malnutrition, anemia or larva migrans syndromes. Preventive measures lie in public education regarding risks related to consumption of raw or undercooked fish. Additional research should aim to elucidate fish-zoonotic parasite transmission pathways, geographic distributions, genetic resistance and diversity, improve diagnostic techniques, and develop evidence-based guidelines for control and eradication. This book chapter reviews major groups of parasitic zoonosis related to fish hosts, focusing on life cycles, epidemiology, pathologic findings in fish and humans as well as diagnosis, treatment and prevention.

Keywords: Parasitic disease, Zoonotic infections, Pathological findings, Transmission routes.

CITATION

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1. INTRODUCTION

Fish are an integral part of the human diet and play a crucial role in global food security. However, consumption of fish also increases the risk of parasitic zoonoses (Shamsi 2019). Parasitic zoonosis refers to diseases caused by parasitic organisms that can spread from animals to humans and cause serious risks to public health. Fish can act as intermediate or definitive hosts for a wide range of parasites, making them potential vectors for these zoonotic pathogens (Lõhmus and Bjorklund 2015).

With the growing global demand for seafood and the expansion of aquaculture practices, parasitic zoonotic diseases in fish have gained increased attention (Shamsi 2020). As more people rely on fish as their primary protein source, it is imperative to understand the transmission, pathogenesis, and prevention of these parasitic infections. This chapter provides an overview of parasitic zoonoses that infect fish, their potential impact on human health, and the importance of effective control measures to mitigate the risks.

1.1. FISH AS INTERMEDIATE HOSTS FOR PARASITES:

Fish serve as intermediate hosts for a diverse range of parasites belonging to different taxonomic groups. These parasites typically complete part of their life cycle within fish, undergoing developmental stages that enable them to infect their definitive hosts, which may include mammals, birds or other aquatic organisms. As intermediate hosts, fish can harbor parasitic larvae, cysts, or eggs that, when ingested by humans, can develop into mature parasites and cause zoonotic infections (Gabagambi et al. 2019).

1.2. COMMON PARASITIC ZOONOTIC DISEASES IN FISH: NUMEROUS PARASITES HAVE BEEN IDENTIFIED AS POTENTIAL

Zoonotic agents transmitted through fish consumption. Among these, certain helminths (worms) and protozoans stand out as significant contributors to parasitic zoonosis. For instance, tapeworms of the genus diphyllobothrium and the liver fluke species Clonorchis sinensis are notorious examples of zoonotic helminths commonly associated with fish consumption (Cong and Elsheikha 2021).

1.3. TRANSMISSION ROUTES TO HUMANS

The transmission of parasitic zoonosis from fish to humans can occur through various routes. The most common method of disease transmission is eating undercooked, raw or poorly prepared fish containing live parasites (Shamsi and Sheorey 2018). Additionally, direct contact with infected fish or contaminated water during recreational activities or occupational exposure in aquaculture and fishing industries can also pose risks of transmission.

1.4. CLINICAL MANIFESTATIONS IN HUMANS

Humans that get parasitic zoonotic infections can have a variety of clinical signs from minor gastrointestinal issues to serious systemic illnesses. The parasite type, the quantity of infectious stages taken in and the immunological health of the infected person are all common factors in determining the severity of an infection. Some parasitic zoonosis may remain a symptomatic for long period therefore there is necessary to make an accurate diagnosis and timely treatment for cure (Bao et al. 2019).

1.5. IMPACT ON PUBLIC HEALTH AND AQUATIC ECOSYSTEMS

Parasitic zoonotic diseases in fish can have substantial implications for both human health and the balance of aquatic ecosystems. Human infections can lead to increased healthcare costs, reduced productivity, and in severe cases, life-threatening conditions. Moreover, heavy parasite problems in fish populations can affect their growth, reproduction and survival, potentially disrupting aquatic food chains and ecological stability (Buchmann 2022).

1.6. FISH-BORNE TREMATODE INFECTIONS

Various other trematode parasites, such as heterophyidae and echinostomatidae which can be transmitted to humans through infected fish consumption (Caffara et al. 2020) . These parasites can cause gastrointestinal symptoms and other health issues.
Parasitic zoonosis in fish refers to the transmission of parasitic infections from fish to humans, leading to potential health risks. The most common method of disease transmission is zoonotic disorders which can naturally spread from animals to people. Fish can harbours various parasitic organisms and when humans come into contact with infected fish or consume raw or undercooked fish, they may become infected with the parasites. These parasites can cause a variety of health problems in humans and some can be severe or even life-threatening, particularly in individuals with weakened immune systems. Here are certain parasitic diseases listed in table and explained below:

Sr. No.	Disease	Etiology	Fish organ affected
1	Anisakiasis	*Anisakiasis spp.*	Digestive tract
2	Echinococcosis	Tapeworm species	Eggs of fish
3	Clonorchis	*Clonorchis sinensis*	Liver and bile ducts
4	Gnathostomiasis	*Gnathostoma spp.*	Skin, muscle and eyes
5	Diphyllobothriasis	*Diphyllobothrium spp.*	Digestive tract
6	Heterophyiasis	*Heterophyes spp.*	Digestive tract

2. PARASITIC DISEASES

2.1. ANISAKIASIS

The most common parasitic disease of marine fish and squids is anisakiasis, caused by the nematode *Anisakis simplex*. The disease is known to be zoonotic which means it can be transmitted from fish to humans (Eiras et al. 2018). Anisakiasis is caused by the *Anisakis simplex* nematode which can infect marine fish and squid.

2.1.1. OUTBREAK

Anisakiasis outbreaks have been documented in a number of places, notably in Japan and other nations where raw fish eating is popular. Between 2018 and 2019, The center of disease control and prevention (CDC) documented 19737 cases of anisakiasis (Sugiyama et al. 2022). Molecular identification of larvae revealed 88.4% patients get infected with species *Anisakis simplex.* This zoonotic disease is most common in countries consuming large quantity of seafood (Sugiyama 2010; World Health Organization 2022).

Anisakis simplex is a parasitic nematode that can infect a variety of marine fish and squid. The nematode's life cycle involves three hosts: a marine mammal, a crustacean, and a fish or squid. Humans can become infected when they eat raw or undercooked fish or squid that contain Anisakis larvae.

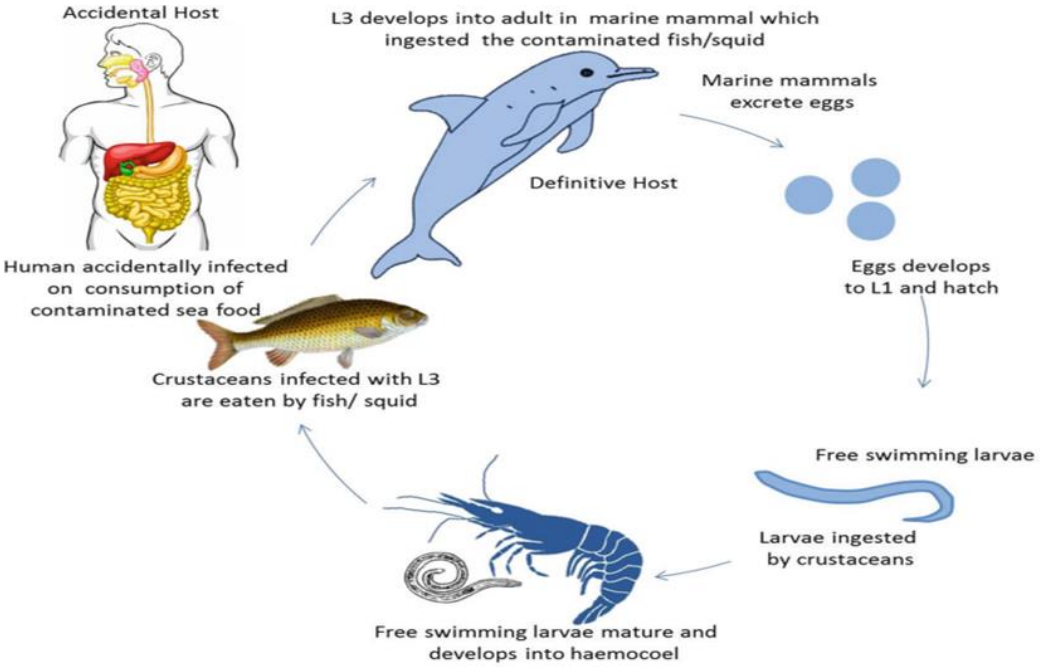

Fig. 1: Life cycle of Anisakis simplex (Tak 2022).

2.1.2. PATHOGENESIS

The most common method of disease transmission is through Anisakis larvae that can enter the digestive tract wall of humans who ingest raw or undercooked fish or squid that has been containing the larvae, leading to inflammation and tissue damage. This may result in symptoms including nausea, vomiting, diarrhea and abdominal discomfort. (Audicana and Kennedy 2008).

The larvae can also be transmitted through contaminated water or by handling fish or squid with bare hands (Mattiucci and Nascetti 2008). The most common cause of anisakiasis in Japan is caused by *A. simplex s.s*. nematodes but in Europe and South Korea *A. pegreffii* is the main culprit. *A. pegreffii* nematodes are frequently removed along with fish viscera when making sushi and sashimi, this may

help to explain why there are fewer cases of *A. pegreffii* anisakiasis in Japan. *A. simplex s.s* nematodes penetrate the muscles of different fish species more readily than *A. pegreffii*. Additionally, fish habitat can support the distinction between South Korea and Japan more popular anisakid nematode species (Suzuki et al. 2021).

Symptoms of anisakiasis typically occur within a few hours after eating infected fish or squid and can include abdominal pain, nausea, vomiting, and diarrhea. In serious situations, the infection may result in problems such as intestinal blockage and allergic reactions. Postmortem lesions associated with anisakiasis may include inflammation and tissue damage in the digestive tract, particularly in the stomach and small intestine.

2.1.3. TREATMENT AND CONTROL

Anisakiasis can be treated with endoscopy to remove the larvae from the digestive tract. In severe cases, surgery may be necessary to remove the larvae and repair any tissue damage. Prevention of anisakiasis involves avoiding eating undercooked fish or squid, especially if it has been discovered that it contains Anisakis larvae. Additionally, the larvae can be killed and the risk of infection is reduced by freezing fish at -20°C for at least 24 hours. (Sakanari and Mckerrow 1989).

Fig. 2: Echinococcosi effect on liver and lungs (Abuseir, 2021)

2.2. ECHINOCOCCOSIS

2.2.1. ETIOPATHOLOGY

The larval stages of cestodes (tapeworms) from the genus Echinococcus are primarily transmit echinococcosis, also known as hydatidosis or hydatid sickness. Cystic echinococcosis is the most common type and is caused by Echinococcus granulosus (sensu lato). Alveolar echinococcosis is caused by a different species, E. multilocularis, which is becoming more widespread. "Neotropical echinococcosis" is linked to two solely New World species, E. vogeli and E. oligarthrus; although E. vogeli produces the exceedingly rarely seen unicystic type, E. oligarthrus causes the polycystic form (Hijjawi et al. 2018).

Ingested eggs from animal faeces hatch in the stomach and release oncospheres, which are juvenile forms of the parasite encased in an embryonic envelope. These eggs may be found on the fur of dogs or

other animals. Through the intestinal wall, oncospheres enter the body and travel through the bloodstream before settling in the liver, these also settle in the lungs or less frequently the brain, the bone or other organs. *E. granulosus* oncospheres change into cysts in tissue and then these cysts progressively develop (typically over several years) to become hydatid cysts which are enormous, fluid-filled unilocular tumours. Within these cysts, brood capsules with countless tiny infectious protocolizes develop. Millions of protocolizes as well as > 1 L of highly antigenic hydatid fluid may be present in large cysts. Sometimes, daughter cysts develop inside or outside of main cysts. A liver cyst that ruptures or leaks might cause an infection to spread to the peritoneum (Thompson 2020).

Hand-to-mouth transmission of live tapeworm eggs from pet waste causes human illness. The parasite eggs, which may survive in the environment for weeks are spread by infected tapeworm animals, dog faeces that contaminate the nearby environment. Infectious protoscoleces originate in cysts that the larvae generate after penetrating the intestinal mucosa, entering the portal system and reaching multiple organs. It is found all across the world but is most common in northern Europe, Asia and North America. Normal hosts for the adult tapeworm include dogs, coyotes and foxes. By using contaminated food and water, people can contract the parasite larval stages. Hydatids in the liver can cause stomach discomfort, nauseousness and vomiting. Chest discomfort, shortness of breath and a persistent cough are clinical indicators that of the lungs infection. The presence and amount of pressure on the surrounding tissues of the hydatid cysts will determine any additional symptoms. Anorexia, weight loss and weakness are non-specific symptoms.

2.2. CONTROL AND PREVENTION

It is controlled by limiting the spread of the parasite. Limiting the locations where dogs are permitted and forbidding animals from ingesting meat contaminated with cysts are two prevention methods. Prevent dogs from eating contaminated dead bodies.

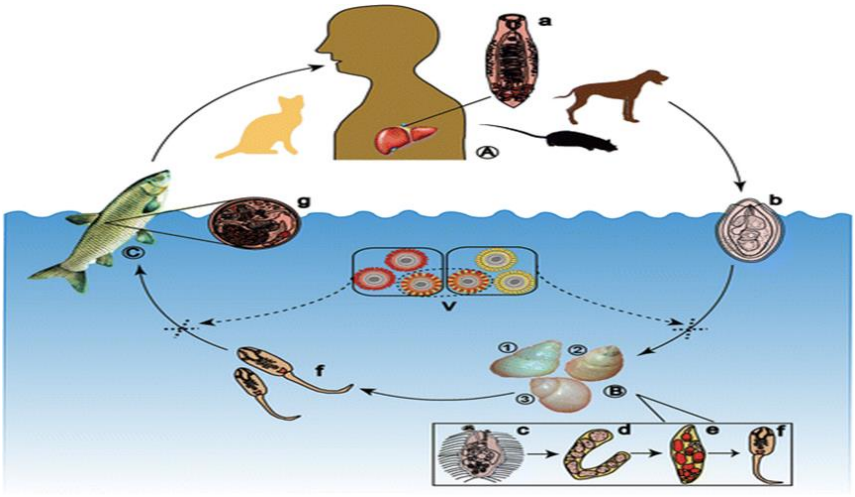

Fig. 3: Clonorchis mode of transmission (Tang et al. 2016).

2.3. CLONORCHIS

2.3.1. ETIOLOGY

The trematode known as *Clonorchis sinensis* which is carried by fish and causes a disease called clonorchiasis. It is also known as the Chinese liver fluke. Most cases of clonorchiasis are brought on by eating fish that has been infected with *C. sinensis* in endemic areas of the world such as East Asia.

2.3.2. PATHOGENESIS

Most infected people are thought to have a benign tumor in the early stages of infection (fewer than 100 flukes) and they rarely ever show symptoms. Acute cholangitis symptoms such as jaundice, right upper quadrant stomach discomfort, nausea, vomiting, anorexia, malaria and fever, can appear in patients with very high parasite loads (>20 000). There are various symptoms involving the liver and biliary system that can be brought on by chronic clonorchiasis. Gallstones, especially calcium carbonate stones are more likely to develop as a result of cholelithiasis which is commonly seen and probably connected to *C. sinensis*. Because of the hyperplastic alterations caused by *C. sinensis*, the gallbladder wall contracts frequently which causes bilirubinate and mucin to precipitate on the parasite eggs (Chamadol et al. 2019).

Clonorchis is primarily transferred when raw or un-cooked contaminated seafood is consumed. Tapeworms can survive in freshwater environments for several years, and can infect a variety of fish species. Most of the Eastern hemispheres of the world, particularly East Asia and portions of Russia are home to *C. sinensis*. It used to be common in Japan as well, but with the mechanization of agriculture after World War II, it has largely disappeared.

Light trematode infections are frequently asymptomatic; symptoms usually appear in people who have had an infection for a longer time or who have a higher worm stress. Heavier infections might result in eosinophilia, hepatomegaly, epigastric pain, fever, chills, and epigastric discomfort during the acute phase. Later, diarrhea might happen. Usually, symptoms continue for two to four weeks. In severe infections, chronic cholangitis can proceed to liver parenchymal atrophy and portal fibrosis. If the biliary tree is blocked by a number of flukes, jaundice may develop.

2.3.3. TREATMENT AND PREVENTION

Praziquantel is the preferred medication for the treatment of clonorchiasis. The World Health Organisation (WHO) advises either 40mg/kg in a single treatment or 25 mg/kg orally three times daily for two to three days to achieve cure rates above 90%. Prevention of Clonorchis involves proper cooking of fish to kill any tapeworm larvae that may be present. Freezing fish at -20°C for at least 24 hours can also kill the tapeworm larvae. Additionally, good sanitation practices and proper disposal of fecal matter can help prevent the spread of infection (Choi et al. 2010).

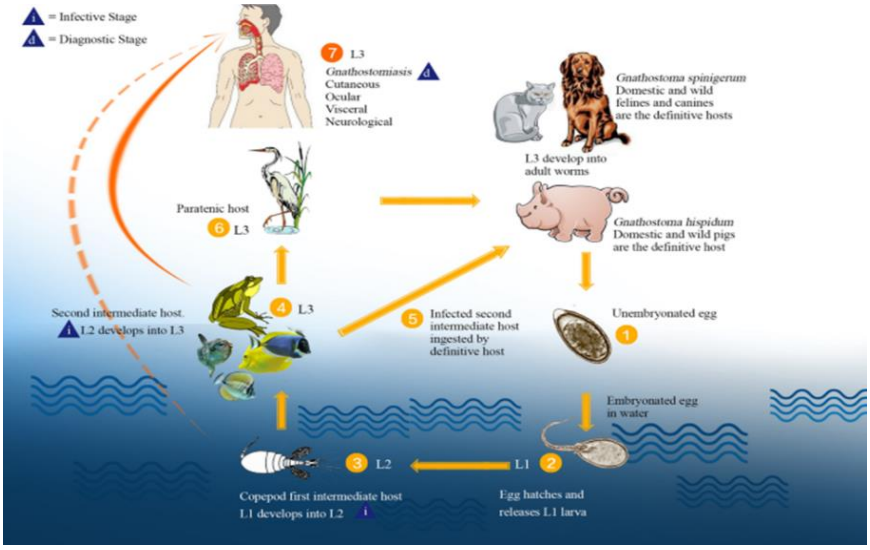

Fig. 4: Infective and diagnostic stages of Gnathostomiasi (Liu et al. 2020).

2.4. GNATHOSTOMIASIS

2.4.1. ETIOLOGY

A zoonotic disease spread by food is gnathostomiasis. its etiological agent is third stage larvae of *Gnathostoma spp.* Human gnathostomiasis is a condition that is often documented in underdeveloped nations as well as in non-endemic regions of advanced countries. The rising intake of reptiles, uncooked freshwater fish, frogs, snakes and poultry that carry L3 larvae is mostly to blame for an increase in human gnathostomiasis cases (Liu et al. 2020).

Eosinophilia and migrating bumps are typical signs of infection. In severe situations, L3 can infiltrate internal organs and tissues including the eyes, spinal cord and brain which can result in blindness, a coma, and even death. It can also cause neurological disorders like paralysis.

The diagnosis can be done on the base of clinical signs Elevated blood eosinophil Living in or traveling to endemic region. Eating undercooked or raw fish or poultry.

2.4.2. TREATMENT

There is no any specific effective treatment for gnathostomiasis. Larvae can be removed surgically and it is the only effective treatment. Surgical removal can only be done in superficial migration. For visceral migration rubrical removal is impracticable, in this case we can give drugs like praziquantel, metronidazole, thiabendazole and quinine. But they do not have obvious efficacy.

2. 5. DIPHYLLOBOTHRIASIS

2.5.1. ETIOLOGY

It is a parasitic disease caused by the tapeworms Diphyllobothrium latum and Diphyllobothrium nihonkaiense. These tapeworms infect a variety of fish, including salmon, trout, and perch, and can be transmitted to humans who consume raw or undercooked infected fish (Richardson et al. 2012). Consumption of contaminated fish results in diphyllobothriasis. The complex life cycle of the tapeworms involves a variety of hosts, including fish and mammals. The adult tapeworms may reach lengths of up to 10 metres and lay up to one million eggs every day which are excreted in the feces of infected host (Kuchta et al. 2017).

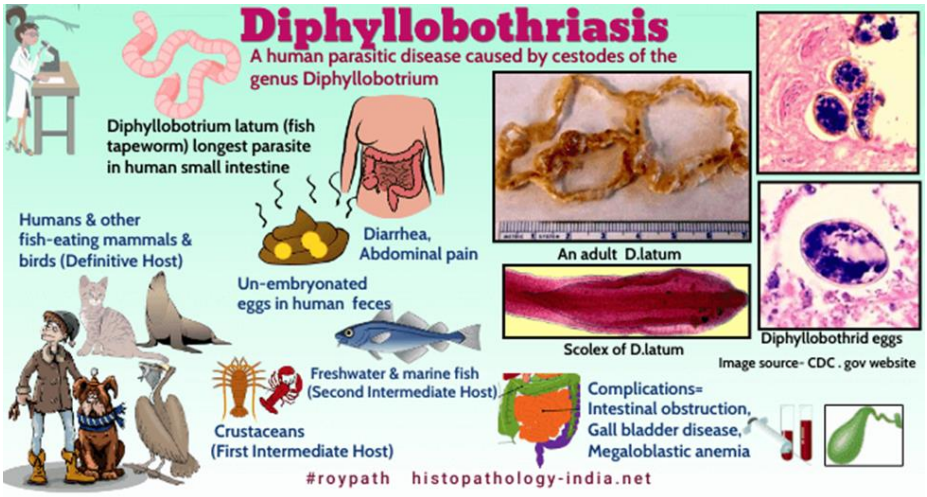

Fig. 5: Diphyllobothriasis life cycle (Dr Sampurna Roy MD).

When humans consume raw or undercooked infected fish, the tapeworm larvae travelled to the small intestine where they attach themselves to the intestinal walls to develop into adult form. These tapeworms can cause a variety of gastrointestinal symptoms, including abdominal pain, diarrhea, and weight loss. In severe cases, they can also lead to vitamin B12 deficiency and anemia (Kuchta et al. 2014).

2.5.2. MODES OF TRANSMISSION

Diphyllobothriasis is primarily transmitted through the intake of raw or under-cooked infected fish. These tapeworms can survive in freshwater environments for several years, and can infect a variety of fish species (Torgerson et al. 2011). Diphyllobothriasis is found world widely however, it is more commonly seen in regions where raw or undercooked fish is a common food source. Outbreaks of diphyllobothriasis have been reported in several countries, including Japan, Russia, and Chile (Ikuno et al. 2018). The clinical signs of diphyllobothriasis can include abdominal pain, diarrhea, and weight loss. In severe cases, it can also lead to vitamin B12 deficiency and anemia. Postmortem examination of fish infected with Diphyllobothrium spp. May show gross and microscopic lesions in the gastrointestinal tract, including inflammation and hemorrhage in the intestine.

2.5.3. TREATMENT AND CONTROL

Diphyllobothriasis can be treated with anthelmintic drugs, such as praziquantel and niclosamide. These drugs work by killing the tapeworms in the intestine, allowing them to be passed out of the body in the feces. Prevention of diphyllobothriasis involves proper cooking of fish to kill any tapeworm larvae that may be present. Freezing the fish for 24 hours at -20°C can kill the larvae of tapeworm. Additionally, good sanitation practices and proper disposal of fecal matter can help prevent the spread of infection.

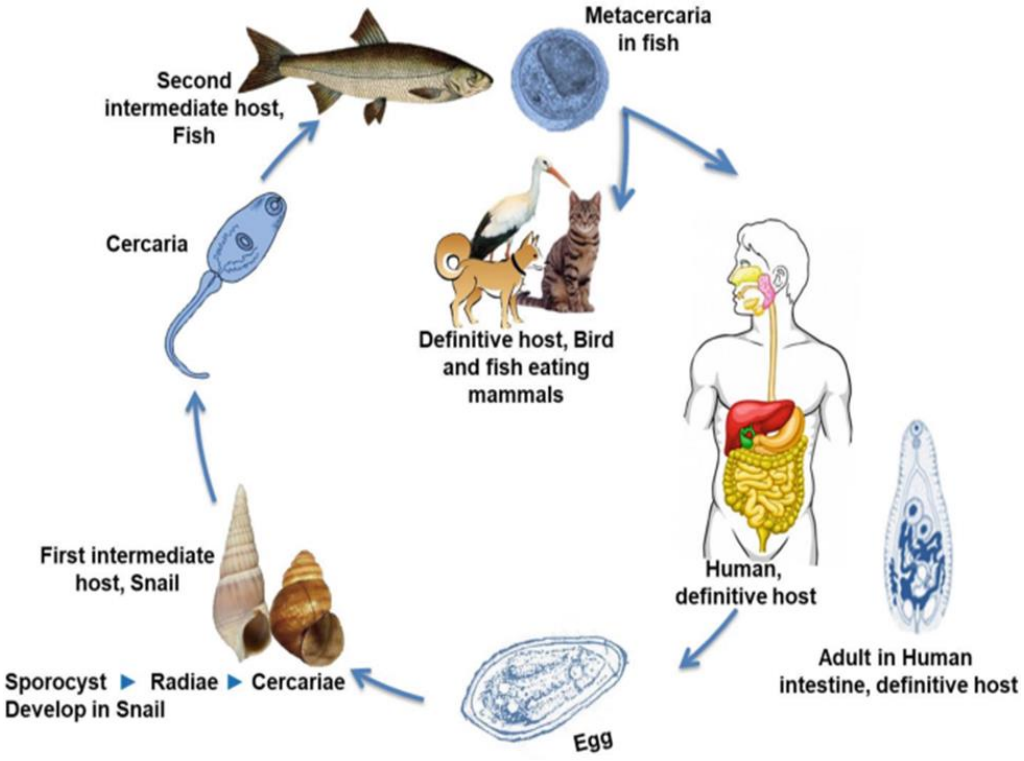

Fig. 6: Life cycle of heterophyiasis (Mahanta 2022).

2.6. HETEROPHYIASIS

- Heterophyiasis is a parasitic infection caused by the trematode worm *Heterophyes heterophyes.*
- The parasite is mostly found in the Middle East, North Africa and the Far East in specific freshwater fish (Hadyait et al. 2018).
- Humans contract the infection by ingesting undercooked or raw infected fish that contain the parasite's larvae (Shamsan and Al-Jobory 2018).
- In the small intestine, the larvae grow into adult worms that cause symptoms such as diarrhea, indigestion, nausea and vomiting (Iqbal and Ashraf 2017).
- The infection may occasionally result in inflammation of pancreas or gallbladder.
- Heterophyiasis is typically treated with the anti-parasitic drug praziquantel.
- Prevention involves avoiding raw or undercooked fish, properly cooking fish, and properly disposing of fish waste.
- Risk factors for heterophyiasis include living in or traveling to areas where the parasite is prevalent and consuming raw or undercooked fish.
- Diagnosis is typically made through a stool sample analysis to identify the presence of the parasite's eggs.
- While heterophyiasis is generally not life-threatening, it can cause significant discomfort and complications if left untreated.

3. PREVENTION OF PARASITIC ZOONOSIS

In fish, the main concern is making sure the fish is fully cooked before eating. The parasites are eliminated from fish when cooked at temperatures that are high enough to kill them. Informing the public about the adverse effects of eating raw or undercooked fish and the need of following the proper guidelines for food safety is also important (Bibi et al. 2015).

It is important to identify and treat parasite zoonosis in fish to reduce hazards to human health and encourage safe fish-eating practices. It is essential to routinely check fish populations for parasites and put appropriate control measures in action for protecting public health and maintaining food safety standards.

Diverse parasites that may spread from fish to humans are the source of parasitic zoonotic diseases in fish. It is critical to understand the mechanisms influencing their transmission as well as the steps to avoid and control these infections because these parasites can complete their life cycles in both fish and humans. The specific requirements are listed below:

3.1. PARASITIC DIVERSITY IN FISH

Protozoa, helminths (worms) and crustaceans are parasites that live within fish. Some of these parasites may infect people and spread disease because they are zoonotic (Poulin 2014). Freshwater fish liver flukes are thought to be present in 45 million humans and 680 million more are thought to be at risk of infection (Saijuntha et al. 2021).

3.2. COMPLEX LIFE CYCLES

Numerous zoonotic parasites have complex life cycles that include numerous hosts. Fish operate as the parasitic intermediate hosts while humans or other mammals become their final hosts, where it matures, reproduces and cause disease (Urdeş and Hangan 2013). In order to stop transmission to people, it is vital to fully understand their life cycles.

3.3. ROUTES OF TRANSMISSION

Fish-borne parasitic infectious diseases can spread to people in a number of ways, by the raw fish, unhygienic conditions and due to improper handling of fish (contaminated water) (Chaisiri et al. 2019). Fish farmers, fisherman, owners all can affected due to water contamination and fish infections due to parasites. Swimmers, divers, and water sport participants come into direct contact with water bodies which contain parasitic zoonotic infections.

3.4. TEMPERATURE FACTOR

Water temperature is one of the ecological components that affects the transmission of parasitic zoonotic infections in fish. Parasite growth and infectiousness are frequently temperature-dependent processes (Wongsaroj et al. 2014). Some parasites life cycles may be accelerated by warmer waters. Stressed fish are more susceptible to disease when the water is contaminated with organic matter or chemicals the incidence of zoonotic parasites can be impacted by the presence of intermediate hosts and vectors in aquatic habitats.

3.5. FEEDING HABITS AND FISH SPECIES

The sensitivity of certain parasites to different fish species may differ. Furthermore, a fish exposure to parasites in the environment can be influenced by its consuming food preferences, such as carnivorous or omnivorous diets.

3.6. CONSUMPTION PATTERNS AND HUMAN BEHAVIOR

Human behavior like food preparation and preferences can significantly impact parasitic zoonotic infections. awareness of the risks and follow management rules make you enjoy a better life, free from pathogens (Broglia and Kapel 2011).

3.7. FISH HEALTH

Fish with a damaged immune system or those under stress are vulnerable to parasite infestations. The incidence of parasites in fish populations can be decreased in aquaculture by proper management and health monitoring (Kuton et al. 2019).

3.8. DIAGNOSTICS AND SURVEILLANCE

Finding parasitic zoonotic infections in fish requires effective diagnostic and monitoring techniques. Regular inspections can spot sick fish and prevent them from getting into the food supply.

3.9. PRECAUTIONS

There are several ways to reduce the danger of parasite-related zoonotic diseases in fish and people: a. Proper Cooking: Killing parasites and ensuring safe eating require cooking fish at the right temperatures. b. Freezing: Freezing fish at the right temperature and for a proper duration of time can help eliminate certain parasites. Implement quarantine and health certification procedures for fish farms and aquaculture facilities. d. Public Education: Inform the general population about the dangers of ingesting raw or undercooked fish as well as the value of good cleanliness (Ziarati et al. 2022).
Fish parasitic zoonotic diseases represent a serious risk to human health and must be controlled and eradicated using a multidisciplinary strategy. Designing efficient measures to protect both fish populations and people who consume them requires an understanding of the mechanisms controlling the transmission, prevalence, and life cycles of these parasites (Cong and Elsheikha 2021).

4. CONTROLLING AND PREVENTING PARASITIC ZOONOTIC IN FISH

Fish parasitic zoonotic diseases are a serious hazard to the health of aquatic animals as well as human populations. Effective preventative measures and control tactics are crucial for preserving public health and the integrity of aquatic ecosystems. Drawing from reputable sources and scientific literature, this section provides an overview of the main preventative strategies and management techniques for parasitic disease outbreaks in fish.

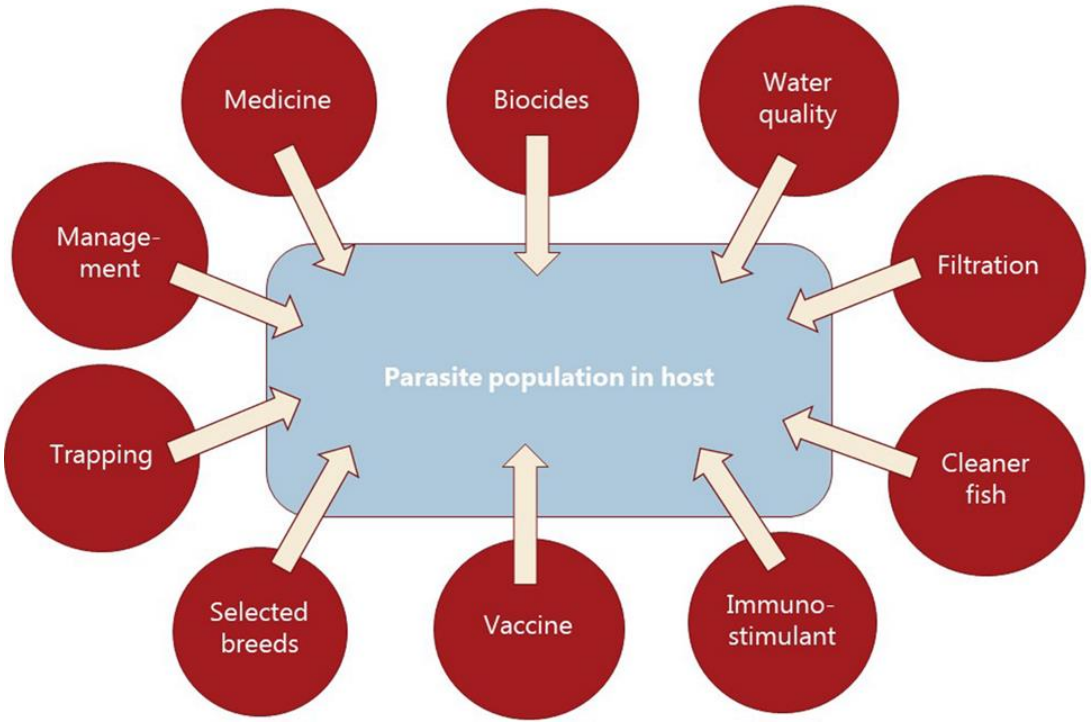

Fig. 7: Control of parasitic diseases in aquaculture (Buchmann, 2022).

4.1. QUARANTINE PROTOCOLS AND BIOSECURITY

- Strict biosecurity controls may be put in place in fish farms and other aquaculture facilities to assist limit the introduction and spread of parasitic infections.
- Before introducing freshly purchased fish stocks to existing populations, quarantine them to evaluate their health state and make sure they are parasite-free.
- Keep a close eye on and check fish shipments often to look for and remove any potential parasite disease carriers (Williams et al. 2022).

4.2. MANAGING QUALITY OF WATER

- Keeping the water at its optimum level is essential to lowering fish stress, which might lower their susceptibility to parasite conditions.
- To ensure a healthy aquatic environment, regularly check water parameters including temperature, pH, ammonia and dissolved oxygen levels.

4.3. PROPER NUTRITION MANAGEMENT

- Giving fish a healthy and nutritious diet helps boost their immune systems and increase their resistance to parasite infection.
- Maintain the proper stocking densities and check for nutritional deficiencies in fish to reduce stress.

4.4. SANITATION

- Follow strict hygiene procedures while handling fish and performing aquaculture activities to avoid cross-contamination.
- Conduct routine cleaning and disinfection of buildings, tanks, and machinery to avoid the accumulation and spread of parasitic germs.

4.5. IPM, OR INTEGRATED PEST MANAGEMENT

Instead of only chemical treatments using an IPM approach can help reduce parasite zoonotic infections. Manage parasite populations by using biological or natural predators and lessen the usage of chemical controls (Falkenberg et al. 2022).

4.6. DISEASE MONITORING AND DIAGNOSIS

- Conduct routine disease monitoring and health inspections on fish populations to look for early indications of parasite diseases.
- Use reliable diagnostic techniques and seek expert help as necessary since accurate diagnosis is essential for effective treatment of an infection (Bardhan 2022).

4.7. USE OF ANTIPARASITIC DRUGS

- When parasitic infections are confirmed use the proper antiparasitic drugs in accordance with the recommended doses and treatment procedures.
- When parasitic infections are confirmed Select the most efficient and secure treatment methods in cooperation with fish health professionals and veterinarians.

4.8. REDUCING CROSS-CONTAMINATION

- Use distinct equipment and nets for each group to avoid cross-contamination between various fish populations.
- To prevent the spread of parasites, isolate sick fish right away from healthy fish to minimize the risk of infection (Williams et al. 2020).

4.9. ENVIRONMENTAL MANAGEMENT

- Evaluate how aquaculture practices affect the environment and natural ecosystems.
- Reducing water pollution and managing waste properly can help to lower the danger of parasite outbreaks.

4.10. PUBLIC HEALTH AWARENESS

- Educate fish farm owners, workers and consumers about the risks associated with fish farming, consuming and trading fish infected with zoonotic parasites

Encourage safe food handling techniques such as appropriate cooking and freezing techniques to destroy parasites.

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