Aquatic Parasites: Their Zoonotic Potential and Impact on Public Health

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Abstract

Aquatic parasites present considerable zoonotic threats, impacting global public health. These parasites include protozoa, helminthes, and ectoparasites that spread by waterborne and foodborne pathways, most commonly through the ingestion of contaminated fish or direct contact with infected water sources. The expanding worldwide seafood trade, combined with environmental changes, has increased the geographical distribution of these parasites. This chapter delves into their taxonomy, life cycles, transmission dynamics, public health consequences, and diagnostic procedures. It also examines preventative and control tactics, highlighting the necessity of multidisciplinary approaches, public awareness, and enhanced biosecurity measures in mitigating the hazards associated with aquatic parasite illness. To stop outbreaks, the importance of integrated surveillance, good hygiene habits, and public awareness is emphasized. The article also discusses the difficulties in monitoring zoonotic parasites and highlights contemporary diagnostic and control methods. Developing successful intervention strategies to safeguard the health of humans and animals requires an understanding of the ecology and epidemiology of aquatic parasites.

Keywords: Aquatic parasites, Fish-borne infections, Parasitic transmission, Zoonotic diseases, Public health

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Introduction

Humans around the globe suffer from various parasitic foodborne and waterborne zoonoses caused by helminthes, protozoa, and larva migrans. These parasites of concern are transmitted from different water sources, marine, brackish, freshwater, and fish. Previously, the low- and moderate-income countries were the main target of these diseases, but the geographical boundaries are expanding as a result of thriving international markets, enhanced transportation systems, and shifts in demographics, and so the population at risk. According to World Health Organization (1995), more than half a billion of population is at risk of fish-borne trematode infection while more than 18 million is currently infected. The significance of this zoonosis for public health and its association with poor living conditions, cultural traditions, increase in of agriculture, degradation of the environment and lack of control measures is now getting widely acknowledged (World Health Organization, 1995; 2004). The diseases inflicted by both unicellular and metazoan parasites also adversely affect the health status and development of both wild and cultured fish (Williams and Jones, 1994; Woo and Buchmann, 2012). Aquatic parasites cause a loss of approximately 10 billion USD annually in aquaculture and fisheries with 1-10% reduction in development of cultured fish and 20% mortality in hatcheries (Selzer & Epe, 2021).

1. Classification of Aquatic Parasites

Aquatic parasites include protozoa, fish-borne and fecal borne helminthes, and aquatic larvae migrans.

1.1 Protozoa

Most common are coccidian.

1.1.1 *Giardia* spp.

Giardiasis is a globally prevalent disease caused by *Giardia duodenalis* (*Diplomonadida, Giardiidae*) causing almost 280 million instances of diarrhea per day (Einarsson et al., 2016). About eight species of *Giardia* are known today but only one of them is zoonotic i.e, *G. duodenalis* (Ryan et al., 2019). The *G. duodenalis* is recognized to be a species complex of eight distinct combinations (A-H) (Ryan et al., 2013). Traditonally, the A and B combinations were thought to be the only ones capable of infecting humans but combinations C, D, E and F have also been found in people (Cacciò et al., 2018). The *Giardia* cysts are resistant to the environment and transmission takes place through the intake of contaminated water or directly via feco-oral route (Feng YaoYu & Xiao, 2011). Numerous outbreaks of waterborne giardiasis have been reported till date (Adam et al., 2016). The *G. duodenalis* is more prevalent in contaminated water bodies containing wastes of humans and animals (Fayer et al., 2004). It enters the ocean settings and bioaccumulates in shellfish, making fish consumption a potential source of human giardiasis (Schets et al., 2007; Giangaspero et al., 2014).

1.1.2 *Cryptosporidium* spp.

Cryptosporidium is a significant fish-borne zoonotic protozoan parasite. Freshwater, marine, ornamental and cultured fishes harbor these parasites worldwide (Golomazou et al., 2021). It primarily causes diarrhea particularly in immune-compromised individuals and children (Ryan et al., 2014). The *Cryptpsporium hominis* (mainly anthroponotic) and *Cryptosporidium parvum* (zoonotic) are the true species of zoonotic importance but various animal-associated species have also been known to produce disease in humans including *Cryptosporidium meleagridis, Cryptosporium felis,* or *Cryptosporium canis* (Šlapeta et al., 2013; Ryan et al., 2014). Their oocysts are extremely resistant to harsh environments and thus survive the chlorinated compounds used for treatment of recreational and drinking water (WHO, 2020). In humans, the primary routes of transmission are by consumption of oocyst contaminated water or food or directly via feco-oral route. Research has also reported its presence in shellfish (Gómez-Couso et al., 2004; Schets et al., 2007).

1.2 Helminthes

1.2.1 Trematodes (Flukes)

The Chinese liver fluke, *Clonorchis sinensis***,** is East-Asia's most significant fish-borne zoonotic species (Rim, 1990; Chen MingGang et al., 1994). In certain parts of the globe, liver flukes have always been known to cause disease for a long time. In humans with chronic infection, it produces a variety of clinical signs like choledocholithiasis, pancreatitis, cholangitis and cholangiocarcinoma. It has been observed that the consumption of improperly cooked or raw meat as well as processed fish humans is increasing day by day which is the biggest risk factor for humans. This is due to the massive provision of these products and population migrations (World Health Organization, 2004). *Clonorchis sinensis, Looss, Opisthorchis viverrini, Opisthorchis felineus* and *Metorchis* are the most significant zoonotic species affecting human populations all around the world.

1.2.2 Cestodes (Tapeworms)

The most important cestode parasites that cause fish-borne zoonosis are related to the genus *Diphyllobothrium*. Humans contract this parasite by consuming marinated or raw fish therefore it is more common in countries where its consumption is a frequent practice. As adults they are gastrointestinal parasites of a wide diversity of mammals and piscivorous birds. The intermediate hosts of *Diphyllobothrium* comprise both marine and freshwater fish, particularly andromous species. The cestode is extensively distributed among wild fish, mammals, and birds in the environment, making it an ample zoonotic reservoir that can again contribute to its spread as today it has declined in human populations (Dick et al., 2001).

1.3 Ectoparasites

Copepods (*Ergasilidea* and *Lernaeidae*), isopods (*Branchiura*), and Branchiura (*Argulidae*) are the three major types of *Ergasilidea* parasitic crustaceans, and most of them live as external parasites destroying the economically important aquaculture species (Khan et al., 2006). These parasites are extensively distributed in water bodies of fresh, marine, and brackish water aquaculture systems worldwide. They normally produce a mild disease in their host if they are present in lesser amounts. However, in case of high parasite burden, they inflict severe damage to muscles, gills, and skin which often leads to secondary bacterial infections (Johnson et al., 2004). Among the crustacean fish parasites, the most common ones are copepods. Aquatic ectoparasites themselves don't have any zoonotic importance, but they can harbor various protozoan parasites and helminthes that may pose a serious threat to the human population. Examples of copepod-bearing helminthiasis include: *Gnathostomiasis, Sparganosis,* and *Dracunculiasis*.

2. Life Cycle and Transmission Dynamics of Aquatic Parasites

The zoonotic species of trematodes (*Opisthorchiidae*) have high resemblance in structure, life cycles, and transmission routes, leading to grave difficulties in specific diagnosis. In case of *Chlonorchis sinensis* freshwater snail, mostly *Parafossarulus manchouricus* species, acts as a major vector and ingests the eggs. Inside snail the eggs are converted to miracidia which hatch in intestine or rectum, invade the peri-rectal tissues and develop into sporocysts (Rim, 1982a). After a fortnight, the rediae and then cercarie are formed within sporocyst and they enter intrahepatic lymph space of snail for maturation (Kaewkes, 2003). The cercarie encysts into metacercarie inside the fish host. It is transmitted to the definitive host by ingestion of uncooked, raw, pickled and smoked fish. It affects a broad range of domestic animals and humans as definitive hosts in which the metacercarie excysts in duodenum and migrate to intrahepatic and extrahepatic bile ducts. Maturation to adult stage takes place within 4 weeks of infection (Rim, 1990).

Cestodes represent the largest parasites of humans growing to 2-15 m in length as adults. The life cycles of most of species are not yet known but they are usually very complex and require three hosts for its completion (Rausch & Adams, 2000). Moreover, involvement of additional or paratenic hosts is also possible. Normally the eggs hatch in water and release its motile embryo. A copepod then ingests it and the embryo grows into its first larval stage, the procercoid. The larvae develop into second stage the plerocercoid inside the second intermediate host (anadromous, catadromous or fresh water fish) when an infected copepod is consumed by fish. Depending on the species of *Diphyllobothrium* the site of development inside the fish may vary (Dick et al., 2001). The plerocercoid stage enters the final host, via ingestion of infected fish. This final stage then matures in intestine of final host which are usually fish eating birds or ,mammals. They have a quite broad range of host specific species.

Gnathostoma spinigerum is a zoonotic water-based spirurid nematode that normally infects cats and dogs. Humans become accidently infected with third stage larvae after the consumption of cyclops species. Cutaneous or visceral migration of larvae is a common characteristic of gnathostomiasis. It transfers to humans by consumption of improperly cooked freshwater fish, chicken, eels, frogs or other mammals which are second intermediate hosts. In rare cases, the wound penetration of larvae from infected fish meat or intake of contaminated water having infected cyclops may also produce disease in humans (Daengsvang, 1976). The infective larvae continuously migrate in human tissues through viscera and subcutaneous tissues and cause intermittent swellings. It also causes irreversible blindness in rare cases by penetrating brain and intraocular tissues (Vejjajiva, 1978; Punyagupta et al., 1990). Figure 1 shows life cycle of *Gnasthostoma spinigerum*.

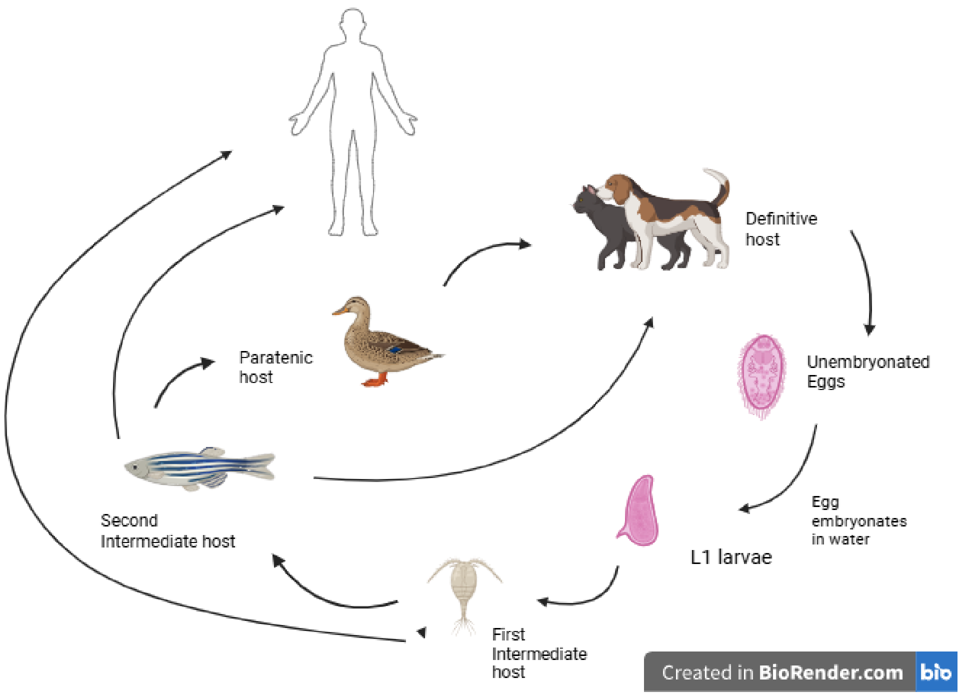

Fig. 1: Lifecycle of *Gnathostoma spinigerum*

Sparganosis is caused by a copepod infected with a metacestode of the genus *Spirometra*. It is a rare zoonotic disease of humans mostly found in Asia, South America (Particularly northeastern, northern and central parts of Thailand) as only 36 cases have been reported till date (Phunmanee et al., 2001; Settakorn et al., 2002). Two intermediate hosts are required for the completion of its life cycle. The metacestode infects the copepod (first intermediate host) which is then ingested by any of the variety of vertebrates like fish, reptiles, rodents, birds and non-human primates. Humans get infected by the ingestion of contaminated water having the first intermediate host or raw and uncooked meat of second intermediate host. Furthermore, it can also spread to humans if the poultice, used to enhance wound healing process, is made of infected meat of intermediate host (Markell et al., 1992). Following entry inside the body, it quickly migrates to different body parts and ultimately localize in subcutaneous tissues, forming nodules. It most frequently damages the eyes (24%), beneath the skin of abdomen (60%) and rarely brain and lungs (Tesjaroen, 1991; Phunmanee et al., 2001).

Dracunculus medinensis also known as the guinea worm is also a waterborne disease transmitted by infected copepods affecting major parts of Pakistan, India and East and West Africa (Imtiaz et al., 1990; Hopkins et al., 1995). Pakistan National Guinea Worm Eradication program (GWEP) aimed at awareness of general public showed that dracunculiasis can be avoided by filtration of drinking water through cloth to remove the copepods (Nithiuthai et al., 2004).

3.Transmission Routes: Waterborne and Water-based

Transmission of zoonotic parasites can be both waterborne and water-based. There are specifically two main ways of human diseases. First, direct contact of open wounds/skin abrasions with infectious agents through fish mucus/feces also called waterborne transmission. Second is water-based transmission, in which the parasite completes a stage of its life cycle inside an intermediate host, and humans are infected by the consumption of uncooked or raw meat of infected fish and fish products. Around 46% of fish-derived zoonotic diseases have been transmitted orally, and 15% follow different transmission routes. Transmission by consumption of infected water is 24% and by direct contact with an infectious agent through skin wounds is 19% (Raissy, 2017). Infection in humans is also dependent on various factors like potency and type of the parasite, host health status (presence of open wounds or immune-compromised) and environmental factors (Haenen et al., 2013).

4. Public Health Implications and Global Burden of Aquatic Parasitic Diseases

Owing to the tiny size of protozoan parasites they are commonly associated to waterborne outbreaks as compared to helminths. Due to this reason, groundwaters are more at risk to smaller sized *Cryptosporidium* oocysts and *Giardia* cysts. *Cryptosporidium* spp. is the key factor in producing waterborne parasitic protozoan outbreaks as it induced a massive outbreak with 403,000 cases in 1993 in Milwaukee (Mac Kenzie et al., 1994) and so on with 239 outbreaks in duration of 2011 to 2016 (Efstratiou et al., 2017). Similarly, research was conducted to study the 89 waterborne outbreaks with 4321 cases affecting Wales and England with infectious intestinal disease (IID). The results showed that *Cryptosporidium* was responsible for 69% of the cases. In UK and Canada, it is also the major microbial causative agent of outbreaks in recreational waters (Smith et al., 2006). However, despite being distributed worldwide this parasite mostly caused outbreaks in industrialized countries like Europe, New Zealand and North America (Putignani & Menichella, 2010; Baldursson & Karanis, 2011). *Giardia intestinalis* is the major cause of outbreaks in the United States (Kappus et al., 1994). Approximately 3581 hospitalizations and 1.2 million cases of giardiasis occur annually (Scallan et al., 2011). Schistosomiasis is more prevalent in continents like Africa, Latin America and Asia being endemic in 74 countries where it has infected almost 200 million people and another 600 million are at threat of exposure (Chitsulo et al., 2000). Talking about fasciolosis, it has significantly spread since 1980 affecting 2.4 million people in 61 countries and posing threat on additional 180 million people (Haseeb et al., 2002). Dams and ponds have highest prevalence where *L. auricularia rubiginosa* species are abundant. Southeast Asia, Japan, Parts of South America, Thailand, Mexico and Ecuador are famous for gnathostomiasis (Nawa, 1991; Diaz Camacho et al., 2002). *Dracunculus medinensis* outbreaks have been more common in Pakistan, India and East and West Africa (Imtiaz et al., 1990; Hopkins et al., 1995). Helminthes have affected several countries via fecal contamination of water bodies. Cystecercosis is found throughout China affecting health of large number of populations. The main reason is the consumption of pork having *T. solium* and *Cysticercus* parasites (Zhao et al., 1997).

5. Diagnosis and Detection of Aquatic Parasitic Infections

Cellophane thick smear can be made to identify eggs in feces in case of liver fluke infections (Chai et al., 1982). Kato-Katz technique is also effective (Hong et al., 2003). Use of excretory-secretory antigens for serological tests like enzyme linked immunosorbent assay (ELISA) is also employed (Choi et al., 2003). PCR-based techniques have however enhanced the diagnosis by the detection of *O. viverrini* infections in fish and snails (Maleewong et al., 2003). Diagnosis can also be made based on clinical presentations and tests like hypersensitivity, bronchial asthma, painful liver hypertrophy, pancreatitis, cholangiocarcinoma, cholecystitis and biliary tract infection are commom (Sripa, 2003) of which cholangiocarcinoma is the deadliest one (Watanapa and Watanapa, 2002; World Health Organization, 2004). The chemical, mechanical and immunological distress of biliary duct by worms is the primary pathogenesis. The intestinal flukes belonging to the family *Echinostomatidae* produce mild disease exhibiting rarely as duodenal and stomach bleeding and ulcerations. Egg measurements and observation can help in specific diagnosis (Chai et al. 1994). In case of *D. dendriticum*, molecular studies have shown that they have a genetic basis (de Vos et al., 1990) and certain ribosomal genes differentiating the most significant freshwater cestodes, *D. latum* and *D. dendriticum*, have been identified (de Vos and Dick, 1989). *D. latum* and *D. nihonkaiense* differentiating markers have also been discovered (Matsuura et al., 1992). The effective diagnosis of protozoan parasites can be done via immunomagnetic separation and then separation by PCR (for viable cysts and oocysts) or antibody detection. The presence of parasites can also be confirmed by using PCR or nucleic acid probes for example: Cysticercosis, Trichinella, and Toxoplasma. Detection also involves the monitoring of raw and treated waters by large and small volume filtration, flow cytometry, immune-fluorescence, detection with monoclonal antibodies, immunomagnetisable separation, morphology, flocculation morphometry, PCR, electrorotation, fluorescence *in-situ* hybridisation. While *in-vitro* excystation, fluorogenic vital dyes, animal infectivity, PCR of inducible heat shock protein 70, fluorescence in situ hybridization, and reverse transcription PCR are effective ways to check the viability of protozoan parasites (Smith et al., 1993; Jakubowski et al., 1996; Smith & Rose, 1998).

6. Prevention and Control Strategies

Veterinarians and fish-handlers having open wounds or abrasions must limit their exposure to water. Wounds should be covered with topical ointments like triple antibiotics and silver sulfadiazine, gels and tissue gels if water contact is necessary. Appropriate control strategies and monitoring of fish intake provides desired information to effectively prevent and treat zoonotic pathogens (Bibi et al., 2015). Public awareness about microbial diseases and risks of consuming raw seafood will be necessary. Interdisciplinary approaches will assist the implementation of control strategies (Toranzo et al., 2005). Physicians, veterinarians and environmental experts must come together in order to eradicate the risk (Chowdhury et al., 2021). Ponds may harbor a large amount of intermediate hosts if not sterilized and cleaned prior to refilling (Clausen et al., 2012; Tran et al., 2019). Antibiotic treatments are helpful in controlling factors contributing to zoonosis (Durborow, 1999; Shin and Park, 2018). Avoiding skin mucus contact and use of gloves is helpful. However, in case of accidental contact the person must frequently wash hands. Different vectors, inanimate objects, inhalation insects and ingestion may also contribute to dissemination of disease (Boylan, 2011). The best way to avoid risk is by inactivation via heating or freezing at low temperatures (Ahuir-Baraja et al., 2021). One Health approach is found to be effective in the aim to eradicate the zoonotic fish diseases however strong participation of the stakeholders is necessary to overcome these challenges of food safety.

Conclusion

Aquatic parasitic infections are a major public health threat owing to their potential zoonosis and increasing spread. A multidisciplinary approach involving medical, veterinary and environmental experts should be adopted for best management. To lower transmission rates, effective food safety measures, enhanced diagnostic facilities and public awareness play a critical role. The World Health Organization stresses on collaborative efforts from stakeholders across the globe to overcome risks related to aquatic parasites. Control of these infections comprises of addressing environmental factors, improving surveillance and adopting responsible aquaculture practices. Continuous studies and research in the field of aquaculture is needed to eradicate the challenges posed by the parasites on both aquaculture and human health. Reducing zoonotic epidemics requires strict food safety laws, enhanced diagnostic capabilities, public education, and efficient surveillance. To lessen the risks, collaboration between environmental scientists, public health specialists, and veterinarians is essential under the One Health approach. Future research should focus on creating vaccines and innovative control strategies to safeguard aquatic ecosystems and human health.

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