



Review

Fishborne zoonotic parasites and aquaculture: A review

Carlos A.M. Lima dos Santos ^{a,*}, Peter Howgate ^b

^a Rua Cel E. Souza Gomes, 510/cob, 22620-320 Rio de Janeiro, RJ, Brazil

^b 26 Lavender Row, Stedham, Midhurst, West Sussex, GU29 0NS, UK

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ABSTRACT

A large number of parasites infect fish but only a few cause illnesses in humans. Due to their high incidence the following helminth families deserve particular attention: *Opisthorchiidae* and *Heterophyidae* (Class Trematodea, subclass *Digenea*), *Anisakidae* and *Gnathostomidae* (Phylum Nematoda), and *Diphyllbothridae* (Class Cestoda). Humans acquire these fishborne parasitic zoonoses through the consumption of infected raw, undercooked, or inadequately preserved fish. Though the transmission of these parasites through fish caught in the wild has been well documented, the association between cultured fish and human parasitic illness has for long been neglected and it is only recently, during the last 10–15 years, that this association has gained increased consideration. This review summarizes and considers this recent evidence linking fish farming to human pathogenic parasites, and discusses the need and opportunities for prevention and control of these zoonoses.

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1. Introduction

Foodborne diseases caused by helminth parasites transmitted by fish and shellfish products pose major public health problems, and worldwide the number of people at risk, including those in developed countries, is more than half a billion (WHO, 1995, 2004). Some of these parasites are highly pathogenic, and human infection is a result of the consumption of raw or undercooked fish infected by the

parasites (WHO, 1995). The reported incidence of these ichthyozoonoses has increased significantly in recent years for several reasons: the development of new and improved diagnosis, by the increase in raw fish consumption in those countries in which such dishes have commonly been eaten, by the increased consumption elsewhere of regional fish dishes such as sushi, sashimi, ceviche, carpaccio based on raw or minimally processed fish, by the growth in the international market in fish and fish products, and by the spectacular development of aquaculture (Keiser and Utzinger, 2005; McCarthy and Moore, 2000; Nawa, et al., 2005; Robinson and Dalton, 2009).

The association between wild fish and the transmission of foodborne parasitic diseases is well documented, but until recently, few examples had been reported of the transmission of parasites to

* Corresponding author.

E-mail addresses: dossantoscarlos@globo.com (C.A.M. Lima dos Santos), phowgate@clara.co.uk (P. Howgate).

humans directly by the products of aquaculture. Some earlier reviews of fishborne parasites suggested that farmed fish could be vectors of diseases of concern for human health (Howgate, 1998; Kabata, 1985; Paperna, 1991; WHO, 1995), but there was almost no documented evidence for this before about the year 2000. Since then a considerable amount of information has been published concerning the role of aquacultured products in the epidemiology of fishborne zoonoses.

The objectives of this paper are to review recent information on fishborne parasites in farmed fish and to discuss measures for prevention and control of parasitic infections in them. The fishborne parasites come from three main groups: digenetic trematodes, especially species of the families *Opisthorchiidae* and *Heterophyidae*; nematodes, especially species of the families *Anisakidae* and *Gnathostomatidae*; and cestodes, especially species of the family *Diphyllobothriidae*. Of these, the trematodes are of most concern based on the morbidities of the associated diseases. Much of the new information comes from Asia and South East Asia and concerns fishborne trematode (FBT) infections, but new information concerning other parasites and regions will be reviewed. The emphasis is on the scientific evidence and epidemiological facts associating foodborne zoonoses with aquaculture.

Much of the information presented here was retrieved by searching the Internet electronic data banks PubMed, Scirus, Science Direct and Scielo using the keywords fishborne parasites, foodborne trematodiasis, *Opisthorchis*, *Clonorchis*, *Heterophyidae*, *anisakidosis*, *Anisakis*, *Gnathostoma*, and *Diphyllobothrium* in combination with the words “aquaculture” and “fish farming”, and also by searching the Internet directly and by following up bibliographies in published papers.

2. Trematodiasis

Trematodiasis is the infection of humans by trematode parasites. Illnesses caused by the infections are a serious public health problem in Asia and Southeast Asia, but trematodiasis occurs, and cause ill health, in countries elsewhere. Of particular concern are infections by species of the family *Opisthorchiidae*, the liver flukes, especially *Clonorchis sinensis*, *Opisthorchis viverrini* and *Opisthorchis felinus*. The taxonomy of trematodes is summarized in Kaewkes (2003) and Keiser and Utzinger (2009). The life cycles of these trematode species are similar and are described in textbooks of parasitology and in several references cited in this review (Kaewpitoon et al., 2008; Kaewkes, 2003; Keiser and Utzinger, 2009; Lun et al., 2005; Sithithaworn et al., 2007). The definitive host is man or other piscivorous animals and there are two intermediate hosts, a snail and a fish. The parasite matures in the definitive host and eggs are shed with the feces of the host. If the eggs reach water they develop into miracidia which are ingested by a snail, the first intermediate host. There they develop and are ultimately shed into the water as motile cercariae which penetrate into the muscle tissue of a fish, the second intermediate host. Human infection takes place through the consumption of raw, undercooked or otherwise under-processed fish containing the infective stage of the parasite (Tran et al., 2009; WHO, 1995). A large number of freshwater fish species can transmit the infective trematode metacercariae with fish belonging to the *Cyprinidae* (carps) being the most common, but not only, family involved in transmission (Chen et al., 2010; Lun et al., 2005; Touch et al., 2009; WHO, 1995). Farmed fish of a variety of species have also been shown to be hosts of trematode parasites (Chi et al., 2008; Hop et al., 2007; Thanh et al., 2009; Thien et al., 2007, 2009; Thu et al., 2007; Thuy et al., 2010). There do not seem to be any new global surveys of numbers of persons infected or at risk from trematode infections since the WHO (1995) report, though there are some data for individual countries in WHO (2004). Keiser and Utzinger (2005) used the frequency of infections from the WHO (1995) report and updated the numbers at risk using the 2004 values of populations in the countries where the parasites are endemic to give revised estimates of 601.0, 293.8, and 79.8 million people at risk

of infection with *Clonorchis sinensis*, *Paragonimus* spp., and *Opisthorchis* spp., respectively, a total of 975 million. Lun et al. (2005) estimated that 35 million persons globally could be infected by *C. sinensis* including 15 million in China (Zhou et al., 2008). Of the diseases due to liver flukes, clonorchiasis is endemic in South China, Taiwan, South Korea and North Vietnam (Cho et al., 2008; Dung et al., 2007; Rim, 2005; Zhang et al., 2007), opisthorchiasis caused by *O. viverrini* is endemic in Thailand, Lao, Cambodia and Central Vietnam (Andrews et al., 2008; Hurtle, 2008; Sayasone et al., 2007; Senior, 2009; Sithithaworn and Haswell-Elkins, 2003; Touch et al., 2009), while that due to *O. felinus* is found in Russia and countries of Central Europe (Yossepowitch et al., 2004).

Generally, infections by liver flukes are asymptomatic, but high levels of infection and chronic infection cause damage to the bile duct epithelium, eliciting gastrointestinal problems, damage to the liver, and possibly cholangiocarcinoma (Choi et al., 2004; Kaewpitoon et al., 2008; Lun et al., 2005; Rim, 2005; Sripa, 2003). *C. sinensis* and *O. viverrini* have been rated as Class 1 carcinogens by the International Agency for Research on Cancer, (WHO, 2011).

Another group of foodborne trematodes that transmit parasitic diseases to man is that of the so-called ‘minute intestinal flukes’. There are approximately 70 species (14 families and 36 genera) within this group of pathogenic parasites with those belonging to the family *Heterophyidae* (the largest among them) being the more important due to their higher incidence. Among *Heterophyidae* noteworthy genera are *Heterophyes*, *Haplorchis*, *Metagonimus*, *Ascocotyle* (*Phagicola*) and *Centrocestus* (Chai, 2007; Chai et al., 2009; Fried et al., 2004; Toledo et al., 2006; Yu and Mott, 1994). Their life cycles are typical of those of trematode parasites with humans and other animal species as definitive hosts, a variety of snail species as first intermediate hosts, and a variety of freshwater, brackish water, and marine fishes as secondary hosts (Chai, 2007). Their epidemiology and pathogenicity are not well understood and the clinical aspects of the illnesses caused need further study. When compared with the illnesses caused by liver flukes, infection with intestinal trematodes do not generally present significant clinical symptoms, however, some heterophyidae species can cause significant pathology, often fatal, in the heart, brain and spinal cord of humans (Chai, 2007; Toledo et al., 2006). It is thought that approximately 18 million individuals could be infected globally by these trematodes (Fried et al., 2004).

Heterophyid eggs are difficult to differentiate from those of liver flukes in human fecal samples and this situation may result in inaccurate estimates of the prevalence of both trematode groups, inaccurate estimates of incidences and intensities of infection by the two groups, and misdiagnosis and inappropriate treatments of illnesses (Chai and Lee, 1990, 2002; Ditrach et al., 1992; Kaewkes et al., 1991; Lee et al., 1984). New diagnostic techniques are increasingly being used to improve specific diagnosis of these flukes (Johansen et al., 2010; Sato et al., 2009).

Several authors have observed that in certain areas where diseases caused by liver flukes have diminished, intestinal fish-borne trematodiasis are now prevalent. This situation has been observed particularly in Taiwan (Ooi et al., 1997), Thailand (Radomyos et al., 1998; Sukontason et al., 1999), and Vietnam (Dung et al., 2007). The explanation for this apparent substitution could be due to improved diagnostic methods, but also other factors contributing to changing patterns in the epidemiology of fishborne trematodiasis, such as population growth, pollution, poverty, changing food habits, might contribute as well. These factors could affect the presence and prevalence of intermediate hosts (snails, fish) thereby influencing the life cycles of different trematode species.

2.1. Trematodes and aquaculture

Aquaculture is one of the most important of the world's food producing activities, and Asia is by far the world's chief aquaculture

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