Fish Parasite: Infectious Diseases Associated with Fish Parasite

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1. Introduction

Parasites have a wide range of distribution in all groups of animals. They are more abundant than free-living animals, and may be found in every phylum of animal from protistan to chordates. A large number and diversity of animal species are capable of patrasitising fish, ranging from microscopic protozoans to easily visible crustaceans and annelids. Most of the fishes, either wild or cultured, are infected with parasites. They not only serve as the host to different parasites, but also serve as carriers of many larval parasitic forms that mature and cause serious diseases in many vertebrates, including man. Parasites exhibit marvelous strategies for adaptation to their hosts. Many parasite species are host-specific to some extent and are capable of infecting one or only a limited number of host species. Individual parasite species may also have widely differing effects on different host species (Roberts 2012). Some of them are parasitic in the external surface of fish; others are parasitic in the internal organs. They can infect fishes in different

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stages of their life, as well as different aquatic environmental conditions, and are also considered to be biological indicators of environmental pollution. Parasites interfere with the nutrition, metabolism, and secretory function of the alimentary canal, damage nervous system, and also upset the normal reproduction of the host.

Most parasite species rarely cause problems in the natural environment but in aquaculture, parasites often cause serious outbreaks of disease (Roberts 2012). They play an important role in determining the productivity, sustainability, and economic viability of aquaculture. Parasite infections cause serious socioeconomic, ecological, and welfare consequences in global finfish aquaculture (Menezes et al. 1990, Barber 2007, Shinn et al. 2015a). They are responsible for direct mortality of farmed stock, retarding growth rate and feed conversion ratios, treatment costs incurred, and rejection of product during processing. Besides direct losses, parasites may have considerable impact on the behavior of fish, reduced fecundity, their resistance to other stressing factors, susceptibility to other infections, the potential legislative burdens, and their presence may also reduce marketability of fish (Williams and Jones 1994, Woo 1995, Schäperclaus 1991, Paladini et al. 2017). Parasites generate costs for managing infections as well as prophylactic treatment in finfish aquaculture. The annual global cost of parasites in finfish aquaculture can be tentatively estimated at $1.05 billion to $9.58 billion (Shinn et al. 2015b). Moreover, many of the parasites are also of zoonotic importance, and have public health consequences. Without stringent and appropriate control measures, the impacts of these pathogens can often be significant. It is therefore an important area for proper attention to be given by the scientists for sustainable and safe fish production. This chapter presents an overview on the important parasitic infections in fish.

2. Protozoan Diseases

Most of the commonly encountered fish parasites are protozoans. They are single-celled organisms, many of which are free-living in the aquatic environment. Their ability to multiply on or within their hosts makes them in many instances very dangerous to fish (Chandra 2004). They have a direct life cycle and mostly reproduce by binary fission; some species have cyst form, off the host. Typically, these parasites are present in large numbers either on the surface of the fish, within the gills, or both. The general effect of these parasites is to irritate the epithelial surface, causing an increasing mucus production. There are three main groups of protozoan parasitising the external tissues of fish: ciliates, flagellates, and amoebae.

2.1 Ciliates

Protozoa belonging to the Ciliophora are equipped with cilia (short, fine cytoplasmic outgrowth), or a structure derived from cilia by secondary modifications, or both. Ciliated protozoa are among the most common external parasites which cause mortalities in a number of wild and farmed fishes. Cilitates can be motile, attached, or found within the epithelium. While they often occur as harmless ectocommensals, under poor environmental conditions or stress, some ciliates can rapidly increase in number, leading to morbidity and mortality.

2.1.1 Ichthyophthiriasis

Ichthyophthirius multifiliis, referred to as 'Ich' is the causative agent of Ichthyophthiriasis or white spot disease. It is the most common pathogen of protozoan parasites of freshwater fishes worldwide (Jessop 1995, Dickerson and Dawe 1995, Buchmann et al. 2001, Matthews 2005, Dickerson 2012). It causes particularly devastating infections in farm-raised fish, where it spreads rapidly within dense populations, leading to extensive morbidity and mortality (Dickerson 2006). Ich infection can occur at any of the growth stages of fish, from fry, fingerling, table size, to brood fish. The parasite can cause catastrophic epizootics in warm and temperate-water fish culture, and may even cause losses in wild fish on occasion. Considerable losses have been reported from cultures of carp, rainbow trout, tilapia, eel, channel catfish, as well as ornamental fish (Ling et al. 1991, Matthews 1994). Ich infections in fingerlings affected about 4% of total channel catfish producers in the U.S. in 2009 (USDA 2010). In Europe, annual losses to trout farmers are estimated to be approximately $140 million per year (Dickerson and Findly 2014). Ich epizootics were reported in China as early as 10th century. The first major outbreak in North America was described in 1898. From 1940, it became a serious disease of carp in Russia. The disease has been reported in fry and fingerlings of Indian major carps from nursery and rearing ponds in Bangladesh (Chandra 2004).

Ichthyophthirius multifiliis is spherical in shape and the cilia are evenly distributed over the whole surface. Characteristic feature of the parasite are the horse-shoe shaped nucleus, and its rotating movement. It is an obligate pathogen and has a unique direct life cycle which allows a rapid intensification of infection (Ewing and Kocan 1992). The life cycle consists of an infective theront, a parasitic trophont, and a reproductive tomont (Nigrelli et al. 1976). Infective theronts swim actively in water in search of hosts. After burrowing into fish epithelium, theronts become trophonts and feed on host tissue until they reach maturity (McCartney et al. 1985). The mature tomont drops off the host, attaches to substrates, and undergoes multiple divisions to produce theronts (MacLennan 1935). The parasite spreads rapidly from fish to fish, as a single lch tomont can produce hundreds to thousands of infective theronts in less than a day (MacLennan 1935, Matthews 2005).

The parasite invades epithelial tissue of gills, skin, or fins, leaving a small wound and visible white spot or nodule where each parasite encysts (Dickerson 2006, Lom and Dyková 1992). Infected fish are extremely lethargic and covered with visible white dots. Mortality can be rapid and catastrophic. Heavy infection by Ich damages fish skin and gills, causes loss of the respiratory, excretory, and osmoregulatory functions, and might serve as a portal of entry for secondary invaders, leading eventually to death of fish (Hines and Spira 1974, Ewing and Kocan 1987, Dickerson 2006).

2.1.2 Trichodiniasis

Trichodiniasis is one of the major protozoan diseases found in fish worldwide. The disease is caused by a large assemblage of peritrichous ciliates of trichodinids. The trichodinid group includes *Trichodina*, *Trichodinella*, and *Tripartiella*, which are important ectoparasites of freshwater and marine fish worldwide (Lom and Dyková 1992). They are capable, in some cases, of causing heavy damage to their hosts, resulting in mortalities. Infestations caused by trichodinids are particularly significant in aquaculture because they are responsible for causing decreased growth (Ekanem and Oblekezie 1996), chronic mortality during cage production (Valladão et al. 2013) and changes in vision and swimming in larvae, culminating in acute mortality (Valladão et al. 2014). Trichodinids have a monoxenic life cycle, and reproduce mainly by binary fission on the host. They can be horizontally transmitted by direct contact or by contaminated water, in which the parasite searches for new hosts. Outbreaks are often associated with poor water quality and stress. Contaminated fish farming utensils are also another important source of transmission of trichodinids.

Trichodinids are up to 100 μm in diameter, and have a basic saucer-shape with a fringe of cilia around the perimeter which are used for locomotion and feeding. Their body is supported by a rigid ring of interconnected discs called a chitinoid or denticular ring. The parasite brows over the surface of gills and skin with spinning motion, damaging the host tissues and consuming the resulting tissue debris. Infected fish often have a grayish sheen due to excess mucus production, and fins may become frayed. Ultimately, erosion of the epithelium will occur (Roberts 2012). The main pathological changes associated with this parasitic infection are related to gill tissue, such as hyperplasia, hypertrophy, oedema, inflammatory infiltration, and necrosis (Yemmen et al. 2011a,b, Valladão et al. 2013, 2014).

2.1.3 Chilodonellosis

Chilodonella is a highly pathogenic holotrich ciliate, ectoparasite on the skin and gill of a wide range of temperate and tropical freshwater fish. The parasite has a flattened, ovoid shape, is up to 80 μm in length, and is covered by rows of cilia which move it in a steady gliding manner over the epithelial cells of its fish host. Heavy infections of *Chilodonella* are often associated with poor water quality. Carps, salmonids, and catfish are the species most commonly affected. *Chilodonella hexasticha* is most likely to be problematic at lower water temperatures, and is reported as a serious pathogen in overwintered carp (Bauer et al. 1973). *Chilodonella piscicola* (=*C. cyprini*) infects cyprinids particularly, but can be found on other fish, where it can cause problems at higher temperatures (Hoffmann et al. 1979). Fingerlings can be especially vulnerable (Urawa and Yamao 1992, Rintamäki et al. 1994).

The mass development of parasite causes a much higher production of mucus and disturbances in the respiratory function of the skin. The fish is restless, and rises to the upper layers of the water. Its entire body is covered with the bluish-white coating, and is particularly noticeable in the head region. A smear in the skin surface reveals numerous individuals of the parasites. Damage to the skin may then be subject to secondary invasion by bacteria, fungi, and other pathogens. It causes localized hyperplasia of the gill epithelium. The thin respiratory epithelium is covered by the hyperplastic epithelium, and this drastically reduces the respiratory surface of the gills.

2.2 Flagellates

Flagellated protozoans are small parasites that can infect fish externally and internally. They are characterized by one or more flagella that cause the parasite to move in a whip-like or jerky motion. Flagella are longer and more powerful than cilia and are always few in number.

2.2.1 Ichthyobodosis

The disease is caused by heavy infections on skin and gills of fish by parasitic flagellates belonging to the genus *Ichthyobodo* (Isaksen 2013). It is an important disease that has caused severe loss among farmed and ornamental fish worldwide for more than a century (Robertson 1985, Isaksen 2013). *Ichthyobodo* is regarded as one of the most damaging parasites among farmed salmon, and is probably the major cause of mortality among salmonid fry and fingerlings (Robertson 1985). The flagellate that is perhaps best known as a serious fish pathogen is *Ichthyobodo necatrix* (=*Costia necator*), which causes the disease known as *costiasis*.

Ichthyobodo spp. spread rapidly between hosts in fish farms, most likely by both direct contact or through free-swimming parasites (Urawa 1996). Heavy infections may occur when conditions favor the parasites. Poor rearing conditions such as low water flow and high crowding densities are considered particularly important (Schäperclaus 1992, Urawa 1995). Massive infections on skin and gills can cause epithelial hyperplasia or hypertrophy, and may result in severe or fatal osmoregulatory or respiratory problems (Urawa et al. 1998). Clinical signs of *Ichthyobodo* spp. are an excess mucus production that forms a blue-grey or white film over the body surface and gills. There have also been described several non-specific clinical signs of severe and prolonged *Ichthyobodo* spp. infections, including flashing, lethargic behavior, listlessness, loss of appetite, and increased mortality (Robertson 1985, Woo and Poynton 1995).

Ichthyobodo spp. are obligate ectoparasites with a direct life-cycle on the host (Becker 1977), and they cannot subsist or multiply without an appropriate host. There are two forms: a parasitic feeding form which attaches to the fish's epithelial cells and a non-feeding, swimming form that exists off the fish (Lom and Dykova 1992). The free-swimming form is kidney-shaped with two pairs of flagella. The attached form is pear-shaped and attaches to the gill and skin (Southgate 1993). The parasites disappear from a dead host, and die after 30–60 minutes in the free-swimming form outside a host.

2.2.2 Hexamitasis

Hexamitiasis is caused by excessive numbers of flagellated protozoa of the genus *Hexamita* in the alimentary tract of farmed and wild freshwater fishes (Southgate 1993). *Hexamitia* sp. is a small (10 µm) pear-shaped, pyriform organism with three anterior and one posterior pair of flagella. *Hexamita truttae* is common in North American trout hatcheries, which cause mass mortality of fish. Clinically, the young fish have anorexia, debilitated with reduced growth, have trailing faecal casts, excessive nervousness, and the abdomen may be distended. The fish develop an acute enteritis, yellowish watery gut contents with numerous organisms present in the faeces or bile from the gall bladder. Transmission is by ingestion of an infective cyst. In farmed Chinook and Atlantic salmon, the disease can become systemic with fish becoming anaemic with swollen kidneys and exophthalmus. *Hexamita salmonis* may be present in vast numbers in the pyloric intestine of cultured salmonids in freshwater, but the degree of damage it causes has been disputed (Uldal and Buchmann 1996). These parasites present a monoxenic life cycle; the pear-shaped trophozoites change to spherical before cellular division (Woo 2006). They can be horizontally transmitted by the releasing of trophozoites and oocysts into the water from the fish feces that will be ingested by other hosts.

2.3 Amoebae

Some free-living amoebae may change their mode of life and become harmful. Several species of amoeba have been implicated in gill disease in salmonids.

2.3.1 Amoebic Gill Disease

Amoebic gill disease (AGD), caused by the free-living, facultative amoeba *Paramoeba* [=*Neoparamoeba*] *perurans*, is a major issue in marine salmon farming, which leads to gill damage and death of infected fish (Mitchell and Rodger 2011). It has become a significant problem in sea-caged Atlantic salmon and rainbow trout in Tasmania, and has been considered the most serious infectious disease (Roubal et al. 1989, Munday et al. 1990, Bryant et al. 1995, Findlay et al. 1995). Cases of gill amoebic infections of fish other than salmonids have also been reported, e.g., in European catfish (*Silurus glanis*) or turbot (Nash et al. 1988, Dyková et al. 1995, 1998, Paniagua et al. 1998).

Clinical AGD most often occurs at water temperatures of 10–20°C, and is sometimes associated with higher than normal temperatures. Gross pathology in infected fish is characterised by raised, multifocal, white mucoid patches on the gills, which represent regions of epithelial hyperplasia of the primary and secondary lamellae. This phase is followed by desquamation of the epithelium, local disturbances of blood circulation, and progressive changes represented by inflammation (Dyková et al. 1995, Adams and Nowak 2001, 2003). All the above mentioned changes result in decrease or loss of gill respiratory surface area. Significant cardiac changes and acid-base disturbances may occur in AGD affected fish, which may result in acute cardiac dysfunction and death (Powell et al. 2002).

3. Metazoan Diseases

Metazoan parasites include the myxozoans, helminths, crustacean, annelids, and mollusks are common in both wild and cultured fish. All have direct life cycle, but the period of their life cycle in which they act as fish parasites varies considerably with the species concerned.

3.1 Whirling Disease

Whirling disease is a chronic inflammatory disease in salmonid fish caused by the myxozoan parasite *Myxobolus cerebralis*, which is characterized primarily by the tight circular movements due to spinal cord constriction and brain stem compression in infected fish (Rose et al. 2000). It occurs worldwide and rainbow trout are most susceptible to disease, although the parasite is able to infect numerous species of salmonid fishes (O'Grodnick 1979, Hoffman 1990). It has been suggested that *M. cerebralis* was originally a parasite of relatively low pathogenicity of native salmonids, such as the brown trout and Atlantic salmon in central Europe. The introduced rainbow trout, on the other hand, is highly susceptible to whirling disease. Through shipments of live and frozen trout, perhaps even with contaminated trout ova, *M. cerebralis* became established in most countries where rainbow trout are cultured. It is now a serious and expanding problem in the native wild populations of rainbow trout and cut-throat trout in the western United States (Bartholomew and Wilson 2002).

Spores of the parasite are oval and have two distinct polar capsules. This protozoan has a complex life cycle. Spores can be shed from infected live fish, as well as from dead and decomposing fish. The spores can also be spread via bird feces. Spores are ingested by an annelid worm intermediate host, *Tubifex tubifex*, which lives in the bottom mud of ponds, streams, and earthen raceways. The spores develop into actinosporeans that penetrate fish (or the fish ingest the actinosporeans when they eat tubifex worms). Plasmodia develop in the fish's cartilage and eventually produce the characteristic spores.

The disease attacks the cartilage. The development and severity of whirling disease depend on the age and size of the salmonid host when exposed to the parasite. Very young fish are most vulnerable to *M. cerebralis*, and susceptibility decreases with age and growth, as bone replaces cartilage in the developing fish (Hoffman and Byrne 1974, Markiw 1991, El-Matbouli et al. 1992, Ryce et al. 2004, 2005). Heavy infections in young fish often result in death. *Myxobolus cerebralis* infections in the spine can cause the fish's tail to turn black and the spine to curve. A blackened tail is caused by pressure on nerves that control pigmentation. Infections in the head cartilage create head and jaw deformities, while infections in the auditory capsule cause young trout to become disoriented and chase their tails in a whirling motion. Permanent deformities of the head, spine, and operculum are caused by cartilage damage, associated inflammation, and interference with normal bone development (Hedrick et al. 1999, MacConnell and Vincent 2002). During the active phase of infection growth rates may be depressed.

3.2 Proliferative Kidney Disease

Proliferative kidney disease (PKD), caused by the malacosporean parasite *Tetracapsuloides bryosalmonae*, is a widespread disease that causes significant losses among farmed salmonids in Western Europe and North America (Hedrick et al. 1984, Morris and Adams 2006). PKD is also the suspected cause for several declines in wild salmonid populations (Burkhardt-Holm et al. 2005, Sterud et al. 2007). The disease is characterized by a chronic inflammation of the anterior and posterior kidney, which is caused by a massive accumulation of lymphocytes and extensive granuloma formation (Ferguson 1981, Clifton-Hadley et al. 1986).

Fish are infected by parasite spores released from bryozoans, which are the invertebrate hosts of the parasite (Feist et al. 2001). The parasite invades the fish through skin and gills (Longshaw et al. 2002), and afterwards invades inner organs, with the kidney being the main target organ for further development (Ferguson 1981, Clifton-Hadley et al. 1986, Kallert et al. 2011). Infection and clinical signs of PKD are dependent on environmental temperature. Water temperatures above 12°C may induce clinical PKD (Morris et al. 2005), but normally, clinical PKD outbreaks occur at water temperatures above 15°C (Tops et al. 2006). It primarily affects fingerling fish, and usually results in 100% morbidity on an affected farm, with up to 20% mortality (Hedrick et al. 1999).

3.3 Diseases Caused by Crustaceans

A tremendous number of crustaceans have evolved to become dependent on certain animals for existence. Those closely associated with fishes can cause disease problems. Parasitic crustaceans are among the most serious gill and skin parasites of fish worldwide. They may be found attached to the external surfaces of both marine and freshwater fish.

3.3.1 Argulosis

Argulids, commonly referred to as ''fish lice'', are obligatory ectoparasites causing problems in fisheries and aquaculture worldwide (Fryer 1968, Kabata 1970, Ahmed and Sanaullah 1976, Post 1987, Rushton-Mellor 1992). About 150 Argulus species are known from marine, brackish, and freshwater habitats (Kabata 1985). *Argulus foliaceus* L. 1758, is probably the most common and widespread argulid in Western Europe. This species has been reported as a threat to the culture of tilapia (Roberts and Sommerville 1982), rainbow trout (Menezes et al. 1990, Ruane et al. 1995), and common carp (Jafri and Ahmed 1994). *Argulus japonicus* Thiele, 1900, is believed to have originated in Japan, and probably owes wide-spread distribution to the trade in ornamental fish, such as goldfish and koi carp (Rushton-Mellor 1992). Argulosis represents a major problem within the Bangladeshi carp culture industry, with infections causing mortality, morbidity, and growth loss (Rahman 1996, Ahmed 2004).

At 5–10 mm, *Argulus* is a large parasite that is visible with the naked eye. Argulids have a very distinctive oval-shaped, flattened carapace. Other notable physical features include compound eyes, a pair of large suckers, four pairs of branched thoracic swimming limbs, and a small unsegmented abdomen. While most fish lice are effective swimmers, many species tend to move through the water in a loose cork-screw motion or a somersaulting action. *Argulus* has a four stage life-cycle (egg, nauplius, meta-nauplius, adult), and requires a fish host at least once during their life. The parasites complete their life-cycle within 30–100 days, depending on water temperature. They are transmitted via free-swimming meta-nauplii stages (Shimura 1981). Once emerged from eggs, non-feeding meta-nauplii actively search for a host (Mikheev et al. 2004). Without a host fish, lice survive only for a few days, and the juveniles for an even shorter period (< 48 hours) (Kollatsch, 1959).

The lice attach themselves to the skin of the host with their strong suckers, and then feed on its host's blood or mucus by using a modified disk which possesses piercing and sucking mouthparts. During feeding, argulids inject cytolytic enzymes and then draw off blood (Shimura and Inoue 1984). Localised inflammation is often seen at the site. In the early stages of infection, an increase in the frequency of fish jumping and a reduction in feeding have been observed. As the infection progresses, secondary fungal and bacterial infections develop and fish may exhibit shoaling behavior (Northcott et al. 1997, Gault et al. 2002). If the infection continues, there may be large-scale mortalities. In addition to their destructive nature, *Argulus* species are known to act as vectors for other pathogens including viruses (Ahne 1985), bacteria (Shimura 1983), fungi (Bower-Shore 1940) and nematodes (Moravec 1994).

3.3.2 Lernaeasis

Lernaenid copepodes or 'Anchor worms' are important ectoparasite parasites in freshwater aquaculture of cyprinids, and occasionally of salmonids and other fishes. Epizootics in cultured fish are often associated with high mortality. The parasites also cause problems in commercial aquariums. Infection by this parasite has been associated with reduced host weight, growth, and fecundity (Kabata 1982, 1985, Khan et al. 2003). The very common *L. cyprinacea* is considered one of the most invasive ones, having worldwide distribution. A number of species have been reported from Indian region (*L. chackoensis* and *L. bengalensis*) (Chandra 2004). Indian major carps are particularly affected by lernaeasis in Bangladesh. Infestations with Lernaea are most prevalent in the summer months and occur more commonly in stagnant or slow-moving water bodies.

Only the female stage is parasitic and is found embedded in the dermis of the fish, sometimes penetrating the musculature and reaching the peritoneal cavity in small fish. Attachment is by means of a branched anchor formed by modification of the head region. The embedded parasite induces a necrotic ulcer around its insertion, and eventually a connective tissue capsule forms around the head of the parasite. Lernaea can cause intense inflammation, leading to secondary bacterial and fungal infections. These secondary infections sometimes worsen and kill the fish. Larger numbers of parasites on the gill can interfere with respiration, causing death. Fish can survive *Lernaea* infection, but chronic conditions frequently result in poor growth and body condition. Mortalities occur most often in young fish, but even if they survive they lose weight and are unsightly (Kabata 1985).

3.4 Disease Caused by Monogenetic Trematode

Monogenetic trematodes are parasitic flatworms or flukes that generally live on the surface of a fish host. Damage is caused to the host by the penetration of their attachment organ and by browsing action of the mouth at the free end. They have been recognized as a serious pathogen of fish in aquaculture (Ogawa 2002, Ernst et al. 2002, Grau et al. 2003). Monogeneans are able to multiply rapidly in high density aquaculture environments because they have a direct single host life cycle, as they require no intermediate host (Rohde 1993). They produce freely deposited eggs that often become entangled to high re-infection rates amongst fish (Ernst et al. 2002, Ogawa 2002). Severely affected fish may die, as a result of gill pathology and interference with the exchange of respiratory gasses and ions (Stephens et al. 2003). Monogeneans display a high degree of host specificity. They can be viviparous or oviparous; are hermaphrodite and commonly protandrous. They attach to their host by means of a specialized muscular posterior attachment organ or opisthaptor, which houses a variable array of sclerotized hooks, connecting bars, clamps, or epidermal structures (Paladini et al. 2017). Two most common representatives of this group are *Gyrodactylus* and *Dactylogyrus*.

3.4.1 Gyrodactylosis

The disease is caused by the genus *Gyrodactylus*. They are commonly known as ‘skin flukes’ and are found all over the surface of the body, including fins and occasionally in the gills of both marine and freshwater fish. *Gyrodactylus salaris* is perhaps the most economically impactful ectoparasitic flatworm of fish which has been responsible for mass mortalities of wild Atlantic salmon when transferred to Norwegian rivers. It is the only notifiable flatworm disease listed by the Office International des Epizooties (OIE) (World Organization for Animal Health) (Bakke et al. 2007). Most species of gyrodactylids are very host-specific and may be even be specific to a particular site on the host (Cone 1995).

Gyrodactylids are small worms, about 0.3–1.0 mm in length, and may just be visible to the naked eyes. Adult parasites carry a fully developed embryo identical to the adult, which in turn carry young of next generation (Eissa 2002). They have a pair of anchors with both dorsal and ventral bars and 16 marginal hooks, and do not have eye spots. Attachment to the fish is made with the marginal hooks; the anchors are used as a spring-like device to assist attachment with the marginal hooks. An embryo with its pair of anchors may frequently be seen inside an adult gyrodactylid. As they are viviparous, gyrodactylids are able to reproduce extremely rapidly if conditions are favorable. Transmission is thought to be by direct fish to fish contact, although parasites may survive for some time in the water column if detached from their host. They move by a characteristic looping action, and small puncture wounds occur each time the hooks penetrate the host. Heavily infected fish may have increased mucus production, frayed fins, skin ulcers, and damaged gills. The lesions are caused by the feeding activity of the parasites. The occurrence of gyrodactylids in epizootic proportions in cultured fish is generally a sign of poor environmental conditions and stressed fish.

3.4.2 Dactylogyrosis

Dactylogyrosis is caused by *Dactylogyrus* species, and in general they are known as “Gill fluke”. Some species of *Dactylogyrus* have proved to be very dangerous in cyprinid culture, especially to fry, where relatively few parasites can cause severe gill damage. The intensity of infestation rises rapidly to reach several hundred per fish. Dactylogyrid flukes are common in freshwater fishes in Bangladesh. A numbers of species of this genus (*Dactylogyrus mrigali, D. chauhanus, D. yogendrai, D. labei, D. kalyanensis*) have been reported from the Indian major carps and from other several exotic and indigenous fishes (Chandra and Jannat 2002, Chandra and Yasmin 2003).

Dactylogyrids have two to four eyespots, one pair of large anchor hooks, and are egg layers. They are oviparous and relatively small. Anteriorly there is a pair of pigmented light receptors and two cephalic lobes, which contains secretions of adhesive gland cells. They have a muscular pharynx and a tubular, posteriorly confluent intestine. The haptor has two pairs of hamuli and 14 marginal hooks. The eggs hatch into free-swimming larvae and are carried to a new host by water currents and their own ciliated movement. Eggs are laid by dactylogyrids embryonate and hatch in a period which varies greatly with temperature within a species and between species. In some species, in temperate climates, eggs laid in autumn may overwinter and hatch on the return of favorable conditions in the spring, when newly hatched fry of host species are available. Dactylogyrids also have optimal temperatures for egg production, resulting in seasonal peaks of infection, and also different geographical distributions between parasite species (Paperna 1964, Bauer et al. 1973).

Clinical signs of fish infected by gill fluke include increased breathing frequency, whilst the gill coverings are stretched open widely, the gill being expanded and very pale. Parts of the gills often become protuberant and show as a small pale fleece outside the covering. Parts of the gill sheets on which flukes have settled are covered with a cloudy film, consisting of slime and destroyed epithelial cells. The gills often suffer from heavy damage. Hyperplastic changes of gill epithelium often spread to areas not colonized by the worm. Telangiectasis (gill blood blisters) is frequent and widespread. Local tissue erosion at the attachment site is accompanied by vigorous peripheral proliferation. Mucus production is over stimulated, seriously impeding respiration. Gills are discolored and swollen so much that normal closure of the opercula may be impossible.

3.5 Diseases Caused by Digenetic Trematode

Digeneans are endoparasitic flatworms, also known as 'flukes' or 'digenetic trematodes', principally infecting the alimentary canal or associated organs. The principal developmental stages of digeneans are called miracidium, sporocyst, redia, cercaria, metacercaria, transitory migrating larva, and adult (Paladini et al. 2017). They have a complicated indirect life cycle with at least one intermediate host. The stage most commonly encountered in fish is the larval metacercaria, which may be found in the tissue within the cyst or unencysted, depending on species. The miracidium is generally ovoid and possesses cilia covering the body that allow the parasite to swim and search for the first intermediate host, which is usually represented by a snail. The final host is usually a piscivorous bird. Damage can occur to the fish when cercarial larvae first invade through the skin of the fish. Some metacercaria are extremely damaging to their target organ, while others cause very little harm, although their presence may be aesthetically unappealing.

3.5.1 Diplostomiasis

Diplostomum spathaceum referred to as 'eye fluke' is the causative agent of diplostomiasis. The parasite invades the lens of many species of freshwater fish in Europe and North America. The infection of eye fluke can cause cataract and blindness in a range of fish species (Dwyer and Smith 1989, Karvonen et al. 2003, Whyte et al. 1991), of which Cyprinids and rainbow trout appear to be particularly susceptible to *D. spathaceum*. The first intermediate hosts are *Lymnaea* spp. and the final hosts are primarily gulls (*Larus* spp.). The metacercariae in the lens cause cataract formation and eventually blindness so that the fish is unable to feed and loses condition. It also becomes more susceptible to predation by piscivorous birds, in which adult parasite is found. The numbers of metacercariae required to cause blindness obviously vary according to the size of the fish. Although the fish is not killed by blinding, its growth rate may be greatly reduced due to its inability to feed normally, and such fish may become emaciated.

4. Fish Leech

Leeches are clitellate annelids and are the only important fish pathogens in the phylum. Aquatic leeches, both freshwater and marine, occur in a diversity of habitats worldwide. Leeches are segmented worms that feed on blood. Armed with suckers at each end of the body, they are able to loop over the body of the fish to feed. Leeches can potentially affect the health of fishes in a variety of ways, but most involve blood-feeding activities. In freshwater, *Piscicola geometra* can reach epizootic levels in rainbow trout and cyprinids cultured in earthen ponds. In the marine environment *Hemibdella* sp. has been noted as a problem on cultured Dover sole and turbot. Some species, however, can on occasion become important fish ectoparasites. Leeches act as vectors or intermediate hosts of protozoan parasites among like *Cryptobia* (Chandra 2004).

The fish attacked by a leech shows, especially during the early stages of attachment, signs of irritation and restless. It may attempt to dislodge the parasite by rubbing against objects. Its movements may become unsteady and erratic. Moribund conditions caused by leeches are easily identifiable because they are accompanied by the presence of large numbers of these parasites. Secondary effects of infections might be more serious than the pathogenic changes. Leeches by themselves are only rarely associated with serious pathological effects. Generally the lesions associated with their blood meals are clean and heal readily once the bleeding stops. Mortalities are rare, and usually the effects of the leeches are restricted to growth reduction (Andersson 1988).

5. Fishborne Zoonotic Diseases

A large number of parasites infect fish, but only a few cause illnesses in humans. Many marine and freshwater fishes serve as a source of medically important parasitic zoonoses that include trematodiasis, cestodiasis, and nematodiasis. Some of these infections are highly pathogenic. These diseases are mainly acquired through eating raw or under cooked fish. Generally, fish can either be intermediate host of parasites involving man as the definitive host, or harbor larval parasites of other animals which can invade human tissues. However, the larval stages of a few species of parasite can mature both in animals and man. The reported incidence of these fish-borne zoonoses has increased in recent years due to the development of improved diagnosis, increase in raw fish consumption in those countries in which such dishes have commonly been eaten, increased consumption elsewhere of regional fish dishes based on raw or poorly processed fish, the growth in the international market in fish and fish products, and the remarkable development of aquaculture (Keiser and Utzinger 2005, McCarthy and Moore 2000, Nawa et al. 2005, Robinson and Dalton 2009).

5.1 Trematodiasis

Trematodiasis is the infection of humans by trematode parasites. Among the fish-borne parasitic diseases, infections by digenetic trematodes are the most common. A considerable number of digenean metacercaria from fish may infect humans. The disease is important in Southeast Asia and the Far East where many people are dependent on freshwater fish as the major source of protein. The most significant of these digeneans are perhaps *Clonorchis sinensis, Opisthorchis viverrini*, and *Opisthorchis felineus* (Roberts 2012, Lima dos Santos and Howgate 2011). A large number of freshwater fish species can transmit the infective trematode metacercariae with fish belonging to the Cyprinidae (carps) being the most common (WHO 1995, Touch et al. 2009, Chen et al. 2010). Farmed fish of a variety of species have also been shown to be hosts of trematode parasites (Chi et al. 2008, Thien et al. 2007, 2009, Thuy et al. 2010).

Clonorchiasis caused by the liver flukes *C. sinensis* is endemic in South China, Taiwan, South Korea, and North Vietnam (Rim 2005, Dung et al. 2007, Zhang et al. 2007, Cho et al. 2008). It is estimated that 35 million persons globally could be infected by *C. sinensis*, including 15 million in China (Zhou et al. 2008). The disease is being associated with biliary obstruction leading to hepatic necrosis, cirrhosis, and portal hypertension, in heavy infections. The parasite may also locate in pancreatic ducts, causing acute obstructive pancreatitis, a most painful condition. Opisthorchiasis caused by *O. viverrini* is endemic in Thailand, Lao, Cambodia, and Central Vietnam (Andrews et al. 2008). It is estimated 6 million humans in Asia may be infected with *O. viverrini*. Human infection due to *O. felineus* is found in Russia and countries of Central Europe (Yossepowitch et al. 2004).

5.2 Cestodiasis

There are relatively few cases of fish-borne cestode infections in man. The cestodes that mature in the small intestine of man are not pathogenic, and diseases are never fatal. Diphyllobothriasis is the major cestodiasis transmitted by freshwater, marine, and anadromous fishes. The disease is caused by pseudophyllid cestodes belonging to the genus *Diphyllobothrium*. At least 13 species of the cestode genus *Diphyllobothrium* have been recognised from humans. The genus is found in fish, mammal, and avian hosts, and is usually associated with cold-water habitats. The species most often reported from humans is *D. latum*, which is relatively common in the Baltic region, the European Alps, eastern Russia and Japan (Dick et al. 2001). It is considered a mild disease; persons infected with the tapeworm may often be symptomless, in others it may cause diarrhea, abdominal pain, and anemia (Dick 2007, Scholtz et al. 2009). Recent estimates indicate that approximately 20 million individuals could be affected by the disease (Scholtz et al. 2009).

5.3 Nematodiasis

Fish-borne nematodiasis are generally caused by the incidental infestation of man with nematodes whose natural definite hosts are marine mammals, birds, pigs, or other animals. Freshwater, brackish, or marine fishes are the second intermediate host. In most infections, the worms can only survive for a limited period after the initial invasion of the gastrointestinal tract. The method of infection is by ingesting the infective larvae which are located in the muscles, intestine, or viscera of fish.

Capillariasis is caused by nematode *Capillaria philippinensis.* The disease was originally presumed to be an indigeneous disease of the Philippines, where an epidemic was first recorded in 1967. Subsequently, the disease was also found in Thailand, Japan, Taiwan, Indonesia, Korea, Iran, Egypt, and India. Freshwater fish may be important as a source of infection of humans with this nematode (Cross et al. 1972). The adult worms are found in the gut of humans, where they can cause a severe and even fatal illness (Cross 1990).

Gnathostomiasis is caused by members of the genus *Gnathostoma* who undergo visceral larval migration. The disease occurs in Southeast Asia, China, Japan, Korea, the Indian subcontinent, and Middle East. Its life cycle is complex involving intermediate (crustaceans and fishes), paratenic (piscivorous birds, reptilian, and small mammals), and final hosts (wild and domestic animals). Man is considered an accidental host in whom the parasite can cause a wide clinical picture, internal or external, where the condition 'larva migrans' is one of the known symptoms (Waikagul and Diaz Camacho 2007).

Anisakiasis refers to infection by larval ascaridoid nematodes if ingested with raw or lightly cured fish (Smith and Wootten 1978). The genera involved are *Anisakis*, *Pseudoterranova*. and *Contracaecum.* Their normal definitive hosts are marine mammals. Larvae (located in squids and marine fish) can invade the gastrointestinal tract of man, causing an eosinophilic granuloma syndrome. In Europe, it has also been referred to as the 'herring worm' disease. These nematodes cannot mature in humans, but may cause a severe allergic reaction with granulomatosis of the stomach wall.

A. simplex causes an acute or chronic infection that may lead to abdominal pain, nausea, vomiting, and/or diarrhea. Some patients develop syndromes exhibiting clinical manifestations of allergy following infection or following consumption of dead larvae (Audicana and Kenneddy 2008). The incidence of the disease varies widely among countries, with Japan reported as having the highest incidence.

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