

## A Comprehensive Review of Major Parasitic Diseases Affecting Culturable Freshwater Fish

### التعليق [WU1]:

- 1-Parasitic Challenges in Culturable Freshwater Fish: A Comprehensive Review"
- 2-Diversity of Parasites Affecting Culturable Freshwater Fish"
- 3-mpact of Parasitic Organisms on Cultivation Freshwater Fish : An Overview"

**Abstract:** In grouper aquaculture, a diverse range of parasitic organisms have been documented to cause substantial issues. Protozoans, particularly ciliates, are the primary source of parasitic illnesses in groupers in the hatchery and nursery phases. Grouper fries are subjected to handling and travel stress when they are transferred to grow-out facilities. Ciliated protozoans, skin, and gill monogeneans and caligid copepods are all common parasites carried by these fish. Protozoans, monogeneans, didymozoid digeneans, nematodes, caligid copepods, isopods and leeches are among the primary parasites of cultivated groupers discussed in this review paper.

### التعليق [WU2]: It is preferable to rewrite the abstract."

**Key words:** Major parasitic diseases, culturable freshwater fish, aquaculture, fisheries.

**Introduction:** Parasites can be found in a wide variety of animal species. They are more numerous than free-living creatures and can be found in every animal phylum, from protists to chordates. Fish can be parasitized by a wide variety of animal species, ranging from minute protozoans to readily apparent crustaceans and annelids. Parasites infect most fish, both wild and cultivated. They are not only hosting for various parasites, but also carriers of many larval parasitic forms that grow and cause significant diseases in many vertebrates, including humans. Parasites have amazing adaptive strategies for their hosts. Many parasite species are host-specific to some extent, with the ability to infect only one or a few host species. Individual parasite species may have vastly varied effects on various host species (Roberts 2012). Some parasitize the fish's external surface, while others parasitize the internal organs. They can infect fish at all phases of their lives, as well as in a variety of aquatic environments, and they are also thought to be biological indicators of pollution. Parasites disrupt the host's regular reproduction by interfering with nutrition, metabolism, and secretory function of the alimentary canal. They also harm the neurological system. In the natural world, most parasite species rarely cause problems, but in aquaculture, parasites frequently cause significant disease outbreaks (Roberts 2012). In finfish aquaculture, parasites produce expenditures for infection management and preventative treatment. The global cost of parasites in finfish aquaculture is estimated to be between \$1.05 billion and \$9.58 billion per year (Shinn et al. 2015b). They are crucial in determining aquaculture's productivity, long-term viability and economic feasibility. In worldwide finfish aquaculture,

### التعليق [WU3]: The references mentions

### التعليق [WU4]: Merge the two sentences because they refer to the same reference

parasitic infections have major economical, ecological and welfare repercussions (Menezes et al. 1990, Barber 2007, Shinn et al. 2015a). They are to blame for direct livestock death, slowed growth rates and feed conversion ratios, treatment expenses, and product rejection during processing. In addition to direct losses, parasites may have a significant impact on fish behaviour, reduced fecundity, resistance to other stressors, susceptibility to other infections, potential legislative burdens, and reduced marketability (Williams and Jones 1994, Woo 1995, Schäperclaus 1991, Paladini et al. 2017).

التعليق [WU5]: Schäperclaus 1991 , Williams and Jones 1994, Woo 1995, Paladini et al. 2017

التعليق [WU6]: The reference mentions

التعليق [WU7]: The references mentions

التعليق [WU8]: The references mentions

التعليق [WU9]: McCarthy and Moore 2000, Keiser and Utzinger 2005, Nawa et al. 2005, Robinson and Dalton 2009

**1. Fishborne Zoonotic Diseases:** There are many parasites that infect fish, but only a handful of them cause illness in humans. Medically important parasitic zoonoses such as trematodiasis, cestodiasis, and nematodiasis are transmitted by a variety of marine and freshwater fish. Some of these illnesses are extremely dangerous. Most of these infections are spread by eating raw or undercooked fish. Fish can either serve as an intermediate host for parasites with man as the ultimate host or they can harbour larval parasites from other species that can infect human organs. A few parasite species' larval stages, on the other hand, can mature in both animals and humans. The reported incidence of these fish-borne zoonoses has risen in recent years because of improved diagnosis, increased raw fish consumption in countries where such dishes are popular, increased consumption elsewhere of regional fish dishes based on raw or poorly processed fish, the growth of the international market for fish and fish products and the remuneration of fish and fish products (Keiser and Utzinger 2005, McCarthy and Moore 2000, Nawa et al. 2005, Robinson and Dalton 2009).

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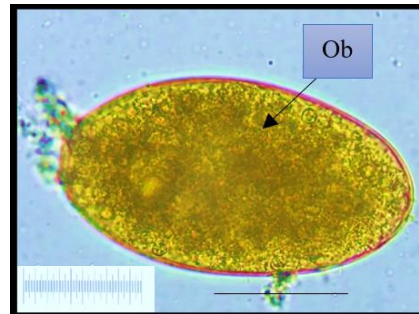
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**1.1 Trematodiasis:** Trematodiasis is a parasitic infection of humans caused by trematodes. Digenetic trematode infections are the most frequent parasite disorders spread by fish. Humans may be infected by many digenetic metacercariae from fish. The disease is particularly prevalent in Southeast Asia and the Far East, where freshwater fish provides a key source of nutrition for many people. *Clonorchis sinensis*, *Opisthorchis viverrini*, and *Opisthorchis felineus* are perhaps the most important digenetic metacercariae (Roberts 2012, Lima dos Santos and Howgate 2011). The infective trematode metacercariae can be transmitted by a variety of freshwater fish species, with Cyprinidae (carps) being the most prevalent (WHO

1995, Touch et al. 2009, Chen et al. 2010). Trematode parasites have also been discovered in farmed fish of several kinds (Chi et al. 2008, Thien et al. 2007, 2009, Thuy et al. 2010).

التعليق [WU12]: Thien et al. 2007, Chi et al. 2008, 2009, Thuy et al. 2010

التعليق [WU13]: This is an egg, not a parasite



Picture: 1: Trematode parasites

**1.2 Cestodiasis:** Infections with cestodes transmitted by fish are uncommon in humans. Cestodes that mature in a human's small intestine are not harmful, and infections are rarely fatal. Freshwater, marine and anadromous fishes all transmit Diphyllbothriasis, the most common cestodiasis. Pseudophyllid cestodes of the species *Diphyllbothrium* are the source of the disease. From humans, at least 13 species of the cestode genus *Diphyllbothrium* have been identified. The genus is found in fish, mammals and birds and is most found in cold-water environments. *D. latum*, which is rather abundant in the Baltic region, the European Alps, eastern Russia and Japan, is the species most frequently reported from people (Dick et al. 2001). It is considered a benign disease; tapeworm infection might be symptomless in some people, but it can also cause diarrhoea, abdominal pain and anaemia in others (Dick 2007, Scholtz et al. 2009). According to recent estimates, the sickness might afflict nearly 20 million people (Scholtz et al. 2009).

التعليق [WU14]: The references mentions

**1.3 Nematodiasis:** The most common cause of fish-borne nematodiasis is an unintentional infection of humans by nematodes whose natural definitive hosts are marine mammals, birds, pigs or other animals. The second intermediate host is freshwater, brackish, or marine fish. After the initial invasion of the gastrointestinal tract, the worms can only live for a short time in most cases. Infectious larvae are found in the muscles, intestine and viscera of fish and are eaten. The worm *Capillaria philippinensis* causes capillariasis. Initially, the disease was thought to be an indigenous sickness of the Philippines when an epidemic was first documented in 1967. In Thailand, Japan, Taiwan, Indonesia, Korea, Iran, Egypt and India, the disease was discovered. Freshwater fish could be a significant source of nematode

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infection in humans (Cross et al. 1972). Adult worms live in humans' guts, where they can cause serious and even fatal sickness (Cross 1990).

**2. Fish Leech:** The only important fish pathogens in the phylum are leeches, which are clitellate annelids. Freshwater and marine aquatic leeches can be found in a variety of settings around the world. Leeches are blood-feeding segmented worms. They may loop over the body of the fish to eat because they have suckers on each end of their bodies. Leeches can harm fish in a variety of ways, although most of them involve blood-feeding activities. *Piscicola geometra* can reach epidemic levels in rainbow trout and cyprinids raised in earthen ponds in freshwater. *Hemibdella* sp. has been identified as a concern on cultured Dover sole and turbot in the maritime environment. However, some species can become major fish ectoparasites on rare occasions. Leeches, like *Cryptobia*, serve as vectors or intermediate hosts for protozoan parasites (Chandra 2004).

**3. Metazoan Diseases:** Myxozoans, helminths, crustaceans, annelids and mollusks are frequent parasites found in both wild and cultivated fish. All have a straight life cycle, although the period during which they operate as fish parasites varies greatly depending on the species.

**3.1 Whirling Disease:** Whirling disease is a chronic inflammatory condition in salmonid fish caused by the myxozoan parasite *Myxobolus cerebralis*, characterised by tight circular motions in afflicted fish due to spinal cord constriction and brain stem compression (Rose et al. 2000). The parasite's spores are oval and feature two polar capsules.

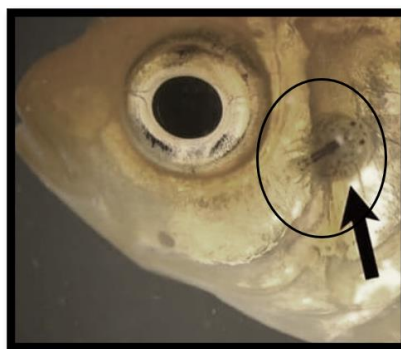
The life cycle of this protozoan is complicated. Infected live fish, as well as dead and decomposing fish, can release spores. Bird droppings can also disseminate the spores. *Tubifex tubifex*, an annelid worm intermediate host that lives in the bottom muck of ponds, streams, and earthen raceways, consumes spores. The spores mature into actinosporeans, which pierce fish (or the fish ingest the actinosporeans when they eat tubifex worms). Plasmodia grow in the cartilage of the fish and produce the distinctive spores.

**3.2 Proliferative Kidney Disease:** The malacosporean parasite *Tetracapsuloides bryosalmonae* causes proliferative kidney disease (PKD), which is a common disease that causes large losses in farmed salmonids in Western Europe and North America (Hedrick et al. 1984, Morris and Adams 2006). PKD is also thought to be the cause of some population decreases in wild salmonids (Burkhardt-Holm et al. 2005, Sterud et al. 2007). Infected fish

are infected by parasite spores secreted by bryozoans, the parasite's invertebrate hosts (Feist et al. 2001). The parasite enters the fish by the skin and gills, then moves on to the inner organs, with the kidney being the primary target organ for future development (Longshaw et al. 2002, Ferguson 1981, Clifton-Hadley et al. 1986, Kallert et al. 2011). The temperature of the environment affects infection and PKD clinical symptoms. Although water temperatures above 12°C can cause clinical PKD (Morris et al. 2005), clinical PKD outbreaks typically occur at temperatures above 15°C (Tops et al. 2006).

**3.3 Diseases Caused by Crustaceans:** A large variety of crustaceans have evolved to rely on specific species for their survival. Diseases can be spread by those who are intimately associated with fish. Crustaceans that feed on fish's gills and skin are among the most dangerous gill and skin parasites on the planet. Both marine and freshwater fish have these attached to their external surfaces.

**3.3.1 Argulosis:** Argulids, also known as "fish lice," are obligate ectoparasites that cause issues in fisheries and aquaculture around the world (Fryer 1968, Kabata 1970, Ahmed and Sanaullah 1976, Post 1987, Rushton-Mellor 1992). Argulus is a big parasite that may be seen with the naked eye, measuring 5–10 mm. Argulids have a carapace that is oval and flattened. Compound eyes, a pair of huge suckers, four pairs of branched thoracic swimming limbs and a tiny, unsegmented abdomen are all remarkable anatomical traits. While most fish lice are capable swimmers, certain species prefer to move through the water in a loose corkscrew or somersaulting motion. Argulus has a four-stage life cycle (egg, nauplius, meta-nauplius, adult) and need the presence of a fish host at least once. Depending on the temperature of the water, the parasites can complete their life cycle in 30–100 days.



Picture: 2: Argulus parasite in fish

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**3.3.2 Lernaeciasis:** *Lernaenid copepodes*, sometimes known as "anchor worms," are important ectoparasite parasites in freshwater cyprinid aquaculture, as well as salmonids and other fish. In cultured fish, epizootics are frequently linked with significant mortality. Commercial aquariums are also affected by parasites. Infection with this parasite has been linked to decreased weight, growth, and fertility in the host (Kabata 1982, 1985, Khan et al. 2003). The common *L. cyprinacea* is one of the most invasive species, with a global distribution. Several species (*L. chackoensis* and *L. bengalensis*) have been reported from the Indian subcontinent (Chandra 2004).

**3.4 Disease Caused by Monogenetic Trematode:** Monogenetic trematodes are parasitic flatworms or flukes that reside on the surface of the fish they infect. The penetration of the attachment organ and the browsing motion of the mouth at the free end cause harm to the host. They have been identified as a major fish disease in aquaculture (Ogawa 2002, Ernst et al. 2002, Grau et al. 2003).

**3.4.1 Gyrodactylosis:** The genus *Gyrodactylus* is responsible for the sickness. Skin flukes are parasitic worms that live on the surface of fish's bodies, including fins and gills. They can be found in both marine and freshwater fish. *Gyrodactylus salaris* is the most commercially significant ectoparasitic flatworm of fish, having caused large mortalities of wild Atlantic salmon when introduced into Norwegian rivers. The Office International des Epizooties (OIE) (World Organization for Animal Health) lists it as the sole notifiable flatworm illness (Bakke et al. 2007). Most gyrodactylid species are host-specific, and some are particularly exclusive to a single place on the host (Cone 1995).



**Picture: 3** Presence of *Gyrodactylus* in fish

**3.4.2 Dactylogyrosis:** Dactylogyrosis is caused by Dactylogyrus species, which are also known as "Gill fluke" in general. Some Dactylogyrus species have proven to be quite harmful in cyprinid culture, particularly in fry, where a few numbers of parasites can cause significant gill injury. Infestation intensifies quickly, reaching several hundred per fish. Dactylogyrid flukes are prevalent in Bangladeshi freshwater fish. *Dactylogyrus mrigali*, *Dactylogyrus chauhanus*, *Dactylogyrus yogendrai*, *Dactylogyrus labei*, *Dactylogyrus kalyanensis*, *Dactylogyrus yogendrai*, *Dactylogyrus labei*, *Dactylogyrus kalyanensis*, *Dactylogyrus yogendrai*, *Dactylogyrus labei*, *Dactylogyrus kalyanensis* (Chandra and Jannat 2002, Chandra and Yasmin 2003).

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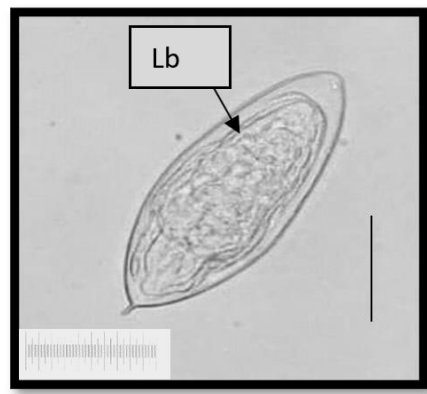


Picture: 4 **Dactylogyrus species**

**3.5 Diseases Caused by Digenetic Trematode:** Digeneans are endoparasitic flatworms that primarily infect the alimentary canal and adjacent organs. They are also known as "flukes" or "digenetic trematodes." Miracidium, sporocyst, redia, cercaria, metacercaria, transitory migrating larva and adult are the main developmental stages of digeneans (Paladini et al. 2017). They have a long indirect life cycle that includes at least one intermediary host. The larval metacercaria stage is the most common in fish and it can be found in tissue within the cyst or unencysted, depending on the species. Miracidiums are ovoid in shape and have cilia covering their bodies, which allow them to swim and look for their first intermediate host, which is usually a snail. A piscivorous bird is frequently the final host. When cercarial larvae initially infiltrate through the fish's skin, they can cause damage.

Some metacercariae are severely harmful to their target organ, whereas others do little or no harm, even if their appearance is unsightly.

التعليق [WU21]: This is an egg of the blood fluke (schistosomiasis)



Picture: 5 Miracidium larva

التعليق [WU22]: Attached are the explanatory images

**3.5.1 Diplostomiasis:** *Diplostomum spathaceum*, also known as the "eye fluke," is the cause of Diplostomiasis. In Europe and North America, the parasite infects the lenses of numerous freshwater fish species. Eye fluke infection can induce cataracts and blindness in a variety of fish species (Dwyer and Smith 1989, Karvonen et al. 2003, Whyte et al. 1991), with Cyprinids and rainbow trout being particularly vulnerable. *Lymnaea spp.* are the initial intermediate hosts, and gulls are the final hosts (*Larus spp.*). The metacercariae in the lens develop cataracts and eventually blindness, preventing the fish from feeding and causing it to lose condition. It also becomes more vulnerable to predation by piscivorous birds, which are known to carry adult parasites. The amount of metacercariae necessary to blind a fish obviously varies depending on its size. Although the fish is not killed by being blinded, its development rate may be considerably slowed because of its inability to feed regularly and it may become malnourished.

**4. Diseases Caused by Protozoans:** Protozoans are microscopic one-celled organisms with specialised locomotion, food collection, and attaching mechanisms. Parasites can be external or inside. They can multiply on or within their hosts. Dinoflagellates, ciliates, myxosporeans and microsporidians are the most common protozoan parasites of grouper. Protozoans make up most common fish parasites. They are single-celled organisms that live in the aquatic environment, many of which are free-living. Because of their capacity to multiply on or within their hosts, they are often quite harmful to fish (Chandra 2004). They have a direct life cycle and primarily reproduce through binary fission; however, some

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species develop cysts that live outside of the host. These parasites are usually seen in great numbers on the fish's surface, within the gills or both. The overall impact of these parasites is to irritate the epithelial surface, causing mucus production to increase. Ciliates, flagellates and amoebae are the three main protozoan types that parasitize fish exterior tissues.

**4.1 Ciliates:** Ciliophora protozoa have either cilia (short, fine cytoplasmic outgrowths) or a structure developed from cilia through secondary alterations or both. External parasitic ciliates are among the most frequent external parasites that kill a variety of wild and farmed fish. Ciliates can be motile, connected to the epithelium or found within it. While most ciliates are innocuous ectocommensals, in the presence of poor environmental circumstances or stress, certain ciliates can rapidly multiply, causing sickness and mortality.

**4.1.1 Ichthyophthiriasis:** *Ichthyophthirius multifiliis* has a spherical shape with evenly scattered cilia across the entire surface. The parasite's horseshoe-shaped nucleus and rotating movement are distinguishing features. It is an obligate pathogen with a one-of-a-kind direct life cycle that allows infection to spread quickly (Ewing and Kocan 1992). An infective theront, a parasitic trophont and a reproductive tomont make up the life cycle (Nigrelli et al. 1976). Infectious theronts actively swim in water looking for hosts. Theronts become trophonts after burrowing into fish epithelium and feed on host tissue until they reach maturity (McCartney et al. 1985). *Ichthyophthirius multifiliis*, often known as 'Ich,' is the organism that causes Ichthyophthiriasis, also known as white spot sickness. It is the most frequent disease of freshwater fish protozoan parasites globally (Jessop 1995, Dickerson and Dawe 1995, Buchmann et al. 2001, Matthews 2005, Dickerson 2012).

**4.1.2 Trichodiniasis:** Trichodiniasis is a protozoan illness that affects fish all over the world. A huge assemblage of peritrichous ciliates of trichodinids causes the sickness. *Trichodina*, *Trichodinella* and *Tripartiella* are ectoparasites of freshwater and marine fish that are found all over the world (Lom and Dyková 1992).

Trichodinids have a basic saucer-shape with a fringe of cilia around the perimeter that are utilised for mobility and eating. They can grow up to 100 micrometres in diameter. The chitinoid or denticular ring, a stiff ring of linked discs, supports their bodies. With a spinning motion, the parasite combs across the surface of the gills and skin, destroying the host tissues and devouring the tissue debris. Excess mucus production causes infected fish to have a grey sheen and their fins may shred. The epithelium will eventually be eroded (Roberts 2012).

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### 4.1.3 Chilodonellosis:

Chilodonella is a highly pathogenic ciliate that lives on the skin and gills of a variety of temperate and tropical freshwater fish. The parasite has a flattened, ovoid shape, can grow to be up to 80 metres long and is covered in rows of cilia that allow it to glide across the epithelial cells of its fish host. Chilodonella infections are frequently linked to poor water quality. The most typically affected species include carps, salmonids and catfish. Chilodonella hexasticha is a significant disease in overwintered carp and is most likely to be a problem at lower water temperatures (Bauer et al. 1973). When a parasite grows in numbers, it produces a lot more mucus and causes problems with the skin's respiratory system. The fish becomes agitated and rises to the surface of the water. The bluish-white coating covers its entire body; however, it is most evident in the head region. A smear of the parasites on the skin surface indicates many of them. Bacteria, fungus and other pathogens may then infect the skin because of the damage. It induces hyperplasia of the gill epithelium in specific areas. The hyperplastic epithelium covers the thin respiratory epithelium, dramatically reducing the gills' respiratory surface.

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### 4.2 Flagellates:

Small parasitic flagellated protozoans can infect fish both externally and inside. They have one or more flagella, which cause the parasite to move in a jerky or whip-like pace. Flagella are longer and stronger than cilia and they are usually in short supply.

**4.2.1 Ichthyobodosis:** The disease is caused by parasitic flagellates of the genus *Ichthyobodo* infecting the skin and gills of fish (Isaksen 2013). It is a serious disease that is wreaking havoc on farmed and ornamental fish all around the world for more than a century (Robertson 1985, Isaksen 2013). *Ichthyobodo* is one of the most dangerous parasites found in farmed salmon, and it is most likely the leading cause of mortality in salmonid fry and fingerlings (Robertson 1985). *Ichthyobodo* spp. are obligate ectoparasites having a direct life cycle on the host (Becker 1977), which means they cannot survive or reproduce without one. There are two types: a parasitic feeding form that adheres to the epithelial cells of the fish, and a non-feeding, swimming form that lives outside of the animal (Lom and Dyková 1992). The free-swimming version has two pairs of flagella and is kidney shaped. The pear-shaped connected form attaches to the gill and skin (Southgate 1993). The parasites vanish from a deceased host and die in the free-swimming form outside of a host within 30–60 minutes.

**4.2.2 Hexamitiasis:** Excessive numbers of flagellated protozoa of the genus *Hexamita* in the alimentary canal of farmed and wild freshwater fishes cause hexamitiasis (Southgate 1993). *Hexamitia sp.* is a pear-shaped, pyriform creature with three anterior and one posterior pair of flagella, measuring 10 µm in length. In North American trout hatcheries, *Hexamita truttae* is common, causing widespread fish loss. Clinically, the young fish are anorexic, emaciated, and have stunted growth, as well as trailing faecal casts, increased anxiety, and a swollen abdomen. Acute enteritis develops in the fish, resulting in yellowish watery stomach contents with numerous organisms present in the faeces or gall bladder bile. Ingestion of an infective cyst is the means of transmission. The disease can develop systemic in farmed Chinook and Atlantic salmon, causing anaemia, enlarged kidneys and exophthalmus. Although *Hexamita salmonis* is seen in large numbers in the pyloric gut of farmed salmonids in freshwater, the extent of the damage it causes is debatable (Uldal and Buchmann 1996).

**4.3 Amoebae:** Some free-living amoebae have the potential to modify their behaviour and become hazardous. Several amoeba species have been linked to salmonid gill illness.

**4.3.1 Amoebic Gill Disease:** The free-living, facultative amoeba causes amoebic gill disease (AGD). *Paramoeba* [=Neoparamoeba] *perurans* is a severe problem in the aquaculture of sea salmon, causing gill damage and mortality in infected fish (Mitchell and Rodger 2011). It has become a major issue with Tasmania's sea-caged Atlantic salmon and rainbow trout and it has been dubbed the most dangerous infectious disease (Roubal et al. 1989, Munday et al. 1990, Bryant et al. 1995, Findlay et al. 1995).

#### COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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UNDER PEER REVIEW



(a)



(b)



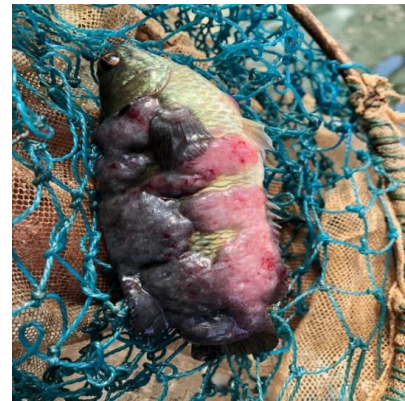
(c)



(d)



(e)



(f)

Fig-1: Parasitic pathogen affect of *Cirrhinus mrigala*, *Ctenopharygodon idella* and *Anabas testudineus*.

التعليق [WU30]: Add other images of the mentioned parasites