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Epidemiology of Helminthes, Protozoans and Ectoparasites of Fishes: A Review

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Abstract

Fish production has a crucial role in food security. However, fish production is decreased by infectious and non-infectious diseases. Parasitic disease is one of the non-infectious diseases that affects the productivity of the fish in the system through decreasing growth rates, spoiling the appearance of fish, lowering the quality and quantity of fish, and low reproduction. The epidemiological occurrence and distribution of parasitic diseases in fish have not been studied in previous research, and most people have not focused on fish health situations. Therefore, the main objective of this review is to provide an overview of the epidemiology of helminths, protozoa, and ectoparasites in fish. The larvae of helminths usually affect the marketability of commercially produced fish, thus raising a lot of public health concerns. Nematodes pose an economic threat to the market value of fish through consumer attitudes towards the presence of these parasites within food products. Adult cestode infections are benign because they are not invasive, but the larval stages penetrate the tissues before encysting, causing obstruction and fibrosis, and sometimes the eggs can lodge in tissues, causing hypertension and a granulomatous reaction. Ectoparasites cause irritation and breathing difficulties that lead to the death of fish. Protozoal diseases of fish can act as ectoparasites and endoparasites that cause mortality in fish. Parasitic diseases can be controlled through the destruction of intermediate hosts and treatment. Generally, parasitic diseases of fish have great health and economic importance for fish farms. Therefore, further studies should be conducted on fish production.

Introduction

Fish has historically played an important role in food security in many nations, and they continue to do so around the world, accounting for 15-20 percent of animal protein intake [1,2]. In both affluent and developing countries, there are several fish species that contribute considerably to food security. Ethiopia has 168 to 183 fish species, with 37 to 57 of them being native to the country. In Ethiopia, the most abundant and marketable fish species are *Oreochromis niloticus (tilapia), Clarias gariepinus*, *Lates species, Barbus species,* and *Bagrus species*. Tilapia is one of the world's most important and highly appreciated fish species as a food source [3-6]. Fishing is crucial for the community's livelihood security since it provides both direct consumption and income. Fish is considered a rich cuisine for impoverished people because it is a relatively inexpensive source of animal protein for humans [7,8]. Several important amino acids, highly unsaturated fatty acids (Omega 3), a high level of miner-

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als (iron, calcium, and iodine), and Vitamin A are all found in fish meat. All these have the importance that they are supposed to help with intelligence, treat skin disorders, brain development, and lower the risk of heart disease, asthma, Alzheimer's, cancer, obesity, and diabetes [9,10,11].

Fish and fishery products remain the most widely traded food items worldwide. International trade is crucial to the fishing sector through the creation of employment, supplying food, generating income, and thus contributing to maintaining food and nutrition security [12,13,14]. Despite the fact that fish production is very productive in both developing and developed countries, fish flesh output in underdeveloped countries is quite low due to fishing development obstacles. The shortage of fish storage, distribution, and marketing facilities; the limited local market; lack of fishing tradition; and fish diseases are major constraints to the development of the fishery [3,15].

Fish have a full range of diseases like all animals, and many of these are due to external agents (microorganisms) and internal agents (organic and degenerative disorders). As research reports, many fish diseases have been causing huge mortality both in aquaculture and capture fisheries, and some have also been causing zoonotic disease in many areas of the world [16-18]. Fish parasitism is one of the constraints that constitute a major threat to fish productivity, and increased demand for fish as a ready and safe source of protein for humans should trigger further studies on fish fauna and their parasites [19]. Periplasmic infestation frequently occurs in fish and is an important factor that affects the productivity of the fish in the system through mortalities by decreasing growth rates, spoiling the appearance of fish and hence lowering the quality and quantity of fish, thus resulting in consumer rejection and affecting the marketability of commercially produced fish in different parts of the country, low reproduction, and making the hosts more susceptible to more pathogenic parasites [20,21,13,22].

The most common parasites that affect fish include nematodes, cestodes, trematodes, acanthocephalans, trematodes, protozoans, leeches, and crustaceans [23,24]. Helminths are highly specialized parasites that require specific, definitive hosts. They frequently occur within the body cavity and viscera of fish. Due to their location in host fish, they may affect one or more important organ systems [25,22]. In fact, the research has been conducted in Ethiopia, in the reservoirs, lakes, and rivers including Lake Tana, Lake Lugo, Lake Ziway, Koka reservoirs, and Gel Gibe River showed that the identified parasites belonged to helminths (nematode, cestode, and trematode), arthropods, and protozoans [26,16,27,28,24]. The epidemiological occurrence and distribution of parasitic diseases of fish have not been conducted in the previous research, and most people did not focus on fish health situations like other livestock. Therefore, the main objective of this review is to provide an overview of the epidemiology of Helminthes, protozoa, and ectoparasites of fish.

Overview the common parasite of fishes

Parasitology deals in fisheries science to define illnesses as a contributor to natural mortality, a measure of environmental effects and human infections transmitted by fish. Fish, like all animals, are vulnerable to a wide range of diseases, some of which are caused by external agents and others by internal factors. Fish are known to be afflicted by external agents such as viruses, bacteria, fungi, and parasites, as well as internal disorders such as nearly all common organic and degenerative diseases. Infestation with parasites is prevalent in fish, resulting in slower growth, decreased production, consumer rejection, low reproduction, and mass mortality [29,30]. Weight loss, impotency, blindness, aberrant behavior, epithelial lesions, gill abnormalities, and other symptoms are the most prevalent symptoms of parasitic infections in fish. All of this finally results in a financial loss for the fish farming sector, with parasites being one of the biggest causes of output losses. Fish parasites, on the other hand, can be found in or on fish in a subclinical or carrier form and do not always cause disease [31,32,33].

Ectoparasites and endoparasites are the two types of parasites found in fish. Internal parasites in fish include flukes (trematodes), tapeworms (Cestodes), spiny-headed worms (Acanthocephalans), and round worms (Nematodes). Ectoparasites are parasites that live on the outside of a host organism, according to [34]. Fish parasites can be plainly visible and are divided into four groups: flukes, leeches (blood suckers), copepods (fish lice), and lampreys (Wondimu, 2020). Within these two classes, parasite types are classified based on the parasite's physical traits, life cycle, and host infection site. Fungi and algae, protozoans, trematodes, nematodes, cestodes, acanthocephalans, parasitic crustaceans, and leeches are some of the parasite types [34,25,35,36].

Helminthes

Helminths are one of the most common types of fish parasites, and they reduce fish output significantly [37]. Platyhelminthes (flat worms), Nematoda (round worms), and Acanthocephala (round worms) are the three major types of helminths that infect fish (spiny-headed worms). A total of 20,000 to 30,000 helminth species have been identified worldwide, resulting in huge losses for the fishing industry [38,39]. Helminthic parasites have been found in freshwater fish in many African countries. Helminthes larvae commonly influence the marketability of commercially produced fish, causing widespread public health issues. Despite the fact that the host tolerates helminth infection, subclinical infections have been linked to significant loss of condition in infected hosts. The clinical signs of infection vary depending on the infection site and duration. Adult and larval helminths (nematodes) move, lodge, and encyst in tissues, causing blockage, oedema, inflammation, anemia, lesions, and granuloma [40,41]. Freshwater fish have been found to host a variety of helminthic parasites. Nematodes, Trematodes (monogenean and digenean), Cestodes, and Acanthocephalans are among them [42].

Nematode

Nematodes (roundworms) are one of the numerous types in the animal kingdom, with 256 families and more than 40,000 species. The phylum Nematoda comprises the classes *Adenophorea* and *Secernentea*, and parasitic nematodes belong to both subclasses (Anderson, 2000). Freshwater fish are often infected by members of *Camallanoide*a and *Ascaroidea*, while marine fish are usually infected by members of the *Ascaridoidoiea* (*Contracecum, Pseudoterranova, Anisakis*), *Camallanoidea (Camallanus, Culcullanus), Dracunculoidea (Philonema, Philometra),* and *Spiruroidea (Metabronema, Ascarophis).* Most of the *camallanoids, dracunculoids,* and *spiruroids* have two host life cycles where fish are the final host [43]. The nematodes have a cylindrical body with an outer cuticle that gives their bodies structural rigidity. The gut begins with a hole and ends with an anus. There is a pseudo-coelom between the gut and the body wall muscles. Nematodes have separate sexes-males and females. Nematodes are common parasites in freshwater and marine fishes [44].

Adult nematodes are typically found in fish digestive tracts. However, depending upon the species of nematode and the species of infected fish, adults and other life stages of nematodes can be found in almost any part of the fish, including the coelomic (body) cavity, internal organs, the swim bladder, deeper layers of the skin or fins, and external muscle layers. [45,41] So, fishes are either intermediate or final hosts for nematodes [43]. Nematodes have adapted to every possible inhabitable environment, from the tropics to the polarregions. They are even noted in desert sand and natural hot springs [46]. Nematodes cause an economic threat to the market value of fish through consumer attitudes towards the presence of these parasites within food products. Infected fillets are rejected and can increase production costs. Fish infected by some parasites could be unsuitable for human consumption, raising a lot of public health concerns [41,45].

Some nematodes are zoonotic and include species such as *Eustrongylides, Contraceacum, Anguillicola, Philometra, Skrjabillanus,* and *Anisakis*. Ingestion of uncooked infected fish meat poses a zoonotic threat to humans. Following ingestion by humans, the larvae are activated by high temperatures, acidic pH, and pepsinogen within the stomach and may cause eosinophilic granulomas of the gut. The bulk of research on nematodes until very recently focused mainly on marine habitats, ignoring the inland water bodies of most parts of the world [41]. Nematodes from African water bodies, except for South Africa, have hardly received any attention to date [47].

General lifecycle of nematode

The life cycles of nematodes differ depending upon the species of nematode. Organisms that contain the reproductive adult stages of nematodes are known as final or definitive hosts. Organisms that are required for the completion of a nematode life cycle but do not contain the final reproductive adult stage are known as intermediate hosts. The direct life cycle of nematodes occurs when an intermediate host does not exist and infection spreads directly from one fish to another via ingestion of eggs or larvae. However, an indirect life cycle occurs when the egg or larvae excrete into the water and, during development, immature stages pass through at least two different organisms, including a definitive (final) host and an intermediate host. In the indirect life cycle, where the fish are considered as the definitive or final host for nematode species (**Figure 1**), If the fish is the definitive (final) host, then the nematode will enter organisms (copepods) in which it will further develop prior to being eaten by the fish. In an indirect life cycle, some nematode species reach sexual maturity and reproduce in these fish. Where fish is an intermediate host, nematodes that have this type of life cycle use species as intermediate hosts only. The final host may be a piscivorous (fish-eating) fish, bird, or mammal. Some nematodes have the ability to survive in alternative organisms known as paratenic hosts. These hosts are not required for completion of the life cycle, but they can contain infective nematode life stages and be a source of infection. They can be fish, worms, or other aquatic organisms that eat the nematode eggs or larvae.

Eustrongylides

Eustronglidosis is a widespread fish disease caused by three species of the Eustrongylides genus: *E. ignotus, E. tubifex,* and *E. excisus*. Eustrongylides species can be found in muscle, free in the body cavity, or encapsulated in the liver and other organs, but they don't reside in fish's intestines. *Eustrongylids* are often long, coiled, and crimson (owing to hemoglobin), and an infected fish may commonly have many nematodes in its body cavity [41]. The indirect lifecycle of the Eustronglides parasite is complicated, involving two intermediate hosts, a paratenic host, and a final host. Intermediate and final hosts give transportation to other hosts as well as a space for the parasite to develop, whereas paratenic hosts just provide transportation to other hosts [48,49].

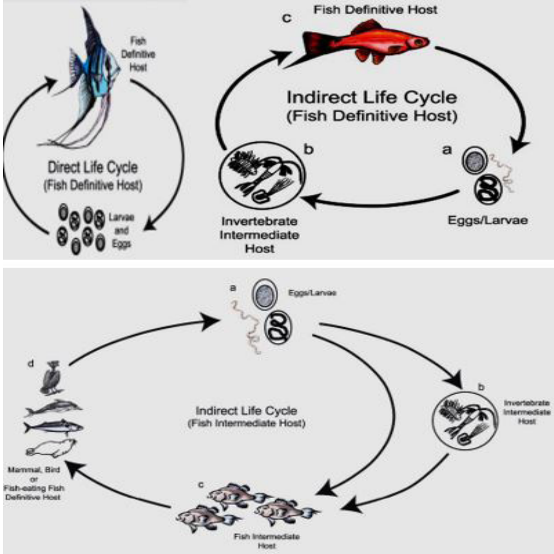

Figure 1: General lifecycle of nematode of fish.

Eustrongylides have five phases in their life cycle, from egg to sexually mature worm. When an infected bird excretes feces into a body of water, the cycle begins. The initial larval stage develops within the egg and is shed in the feces of the infected bird, after which it is swallowed by aquatic oligochaetes like Lumbriculus variegatus, Tubifex, or *Limnodrilus* spp., which represent the first intermediate stage [50]. Planktivorous and benthivorous fishes are the second intermediate hosts, in which the third-stage larvae convert and moult into the fourth larval stage and remain in the fish, most commonly in the muscles, to be consumed by wading birds such as cormorants, the definite hosts [51,48]. Within 3 to 5 hours of infection, the parasite matures into an adult and sheds eggs within 14 to 23 days [49]. The ultimate host where mature nematodes sexually reproduce is known as a definitive host. If the meat is not prepared properly, this parasite species can infect people. In humans, only one worm is required to cause infection [49].

Diagnosis: A necropsy investigation is the most common method of diagnosis for *Eustronglide* species. *Eustroglides* sppss, such as *E. tubifex*, are easily detected during necropsy examination because of their location in the fish (encysted in the mesenteries of the body cavity or in muscle), very long, coiled red color, and relatively lengthy bodies [48,41].

Pathogenesis and clinical signs: Aquatic fish and piscivorous birds are infected by Eustronglides. These parasites' unencysted larvae move beneath the skin and into the muscles of fish, producing widespread inflammation and necrosis. In the viscera, liver, spleen, and gonads, encystation induces significant pathogenic alterations in the surrounding tissue. The parasite changes the bodily state of fish, leaving them more vulnerable to predation rather than sickness [52].

Treatment and Control: Due to the larvae's position in the coelomic cavity and muscle, there is no effective treatment. As a result, the best solution is to cull the infected fish. This parasite can also be controlled by removing the final and intermediate hosts. In addition, pond sanitation will eliminate intermediate hosts.

Capillaria

Capillarid nematodes are a type of nematode that infects a wide range of fish hosts, most typically the intestines. Smooth, cylindrical, big, and somewhat long roundworms of the Capillaria species are regularly found in the guts of fish, and are easily identified by their double operculated eggs in the female worm. Capillaria species have a direct life cycle and can be transmitted from one fish to another through the eating of infective larvae. At 68-73 percent °F, *Capillaria pterophylli* requires three months from infection to mature adult parasites generating eggs or larvae (less time at warmer temperatures). The nematodes achieve sexual maturity after a difficult multi-host life cycle. Any disturbances to these cycles prevent the adult nematodes from developing. Despite the fact that *capillaria* species have direct life cycles, the tubifex worm may operate as a paratenic host, carrying *capillaria* infective stages to the fish.

Pathogenesis and clinical sign: The severity of disease in fish is determined by the life stage, species, and quantity of nematodes present, as well as the age and species of diseased fish and the infection locations. *Capillaries* attach to the intestinal mucosa and feed on it, causing large infections or mesenteric inflammation. Nematode migration and nematode enzymes cause mechanical and proteolytic damage to the mucosa and submucosa. The most common clinical signs of *capillaria* infection in fish include deformed body shape, hemorrhage, mortality, traumatic enteritis, loss of balance due to damage to their swim bladder, reduced swimming performance, lethargy, decreased sexual display rate, ulceration of the gill cover, fraying of fins, large nodules on the ventral surface of the skin, atrophy, and gill ulceration.

Diagnosis: Complete necropsy of a representative sample of the affected population of fish or biopsy of visible lesions can be used to identify capillaria species. Fresh fecal samples are collected instead of necropsy to determine the presence of capillaria eggs, larvae, or adults. Although fresh feces can be inspected for nematode eggs or larvae, a small representative sample of fish must be sacrificed and necropsied on a regular basis. Because Capillaria species are translucent, only juvenile or male nematodes may be present during necropsy. Females have the usual barrel-shaped eggs with a polar plug (operculate) on each end.

Treatment, prevention and control: Capillaria infections can be treated with dewormers such as levamisole or fenbendazole. Like treating animals or humans, few drugs are available for treating disease in fish. Therefore, prevention and control are always the best options, especially against those species of nematode that infect areas other than the gastro intestinal tract of fish. Control can be achieved through a combination of good management practices, the use of a few approved and commercially available drugs, proper sanitation, and the avoidance of carriers.

Contraceacum

In *Contracaecum* spp. in the family *Anisakidae*, has been found in the pericardial cavity and viscera of tilapia. Larval Contracaecum from freshwater fish shows the typical coiled position in the pericardial cavity during postmortem. The larvae of Anisakis may encyst within the muscles of host fish [53]. Contracaecum species have complex life cycles. The eggs are released by gravid females into the intestinal tracts of their definitive (final) hosts, where they are excreted into the water with the feces. The eggs hatch and the free-living larvae develop into the infective third-stage larvae (L3). These L3 larvae are then ingested by an invertebrate intermediate host, within which they develop even further. This invertebrate host is then ingested by the fish intermediate host, where it remains until the intermediate fish host is eaten by the final host (a fish-eating bird or mammal). Some species of *Contracaecum* (*C. spiculigerum*) appear to have no specificity for fish hosts, so they are able to use a wide variety of fish species as intermediate hosts. Contracaecum species have been found in several locations within the body of fish, including the liver, muscles, heart, and swim bladder [46].

Diagnosis: During necropsy of a small group of fish, tentative identification of infection by *Contracaecum* species can be made based upon finding larval nematodes in the locations within the body of the fish, including the liver, muscles, heart, and swim bladder. However, because other nematodes have larvae which may look similar to the larvae of Contracaecum, positive identification of *Contracaecum* infection is diagnosed in the lab [54].

Treatment and prevention: Larval nematodes are found in the intermediate host in locations where they cannot be easily removed by the fish if killed. They are also not necessarily associated with disease. Consequently, chemical treatments, such as dewormers and chemical baths, are not an option and may even incite an immune reaction in the fish [55].

Cestode

Cestodes are members of the Platyhelminthes and comprise about 5000 species from two groups, including *Cestodaria* and *Eucestoda*. The latter are of veterinary importance [56]. Cestodes are endoparasites which require at least one intermediate host in their life cycle and one definitive host to complete their life cycle [57]. Adults in the intestine and plercercoid larvae in the viscera are two stages found in fish when the fish is the definitive host. Aquatic crustaceans normally harbor the plercercoid larvae (Morsy, 2015). In native African fish, a variety of tapeworms, notably unsegmented forms and the segmented *Pseudophyllideans* and *Proteocephalidae,* have been identified. Tapeworms are widespread in Africa, but there are only a few records of tapeworms from different tilapia species. Adult cestode infections are benign due to the fact that they are not invasive, but the larval stages penetrate the tissues before encysting, causing obstruction, fibriosis, and sometimes the eggs can lodge in tissues, causing hypertension and granulomatous reactions [58].

The Cestoda is the name given to a monophyletic assemblage of exclusively parasitic platyhelminths (the Neodermata). The adult body of most cestodes consists of an anterior end called scolex (plural scoleces), which is often significantly modified to serve as an attachment site for the vertebrate host's intestine; a proliferative zone called "neck," and the remaining part of the body, strobila, which houses the reproductive organs. The scoleces of cestodes are typically categorized as either bothriate or trypanonyncha, characterized by the presence of two, or rarely four (Trypanonyncha), longitudinally arranged, shallow depressions called bothria (singular bothrium) [59,60]; it includes *Diphylobothrium* spps, *Proteocephalus glanduliger*, *Polyonchobothrium clarias,* and *Bothriocephalus*.

Most cestode species have at least two hosts in their life cycle: a final or definitive host and an intermediate host. Adult worms (which reproduce sexually) live in the ultimate host, while larvae (also known as metacestodes) develop in the intermediate host. The two hosts are in close proximity, making parasite transmission easier. The cestodes are only transmitted through the food chain from intermediate hosts to final hosts (by food intake or trophic transmission), therefore the intermediate host is a common component of the final host's diet [34]. The general scheme of the life cycle of most aquatic cestodes, including fish cestodes, is as follows: [61] found cestode eggs in the uterus, which may contain embryos named oncospheres (lycophora in Cestodaria), pass with the host's faeces into the environment. Eggs (except those taxa that have coracidium) are eaten by the intermediate hosts (crustaceans). Larvae hatch in the guts of intermediate hosts (with a few exceptions) and use their hooks and glands to penetrate the intestinal wall and locate in body cavities or other internal organs where they metamorphose into infective larval stages. [62] identified six basic types of metacestodes. Three of them can be found in the life cycles of freshwater fish cestodes: procercoid, an alacunate form which cannot develop further until ingested by a second intermediate host (*Diphyllobothriidea, some Bothriocephalidea*); plerocercoid, an alacunate form with an everted scolex (*Caryophyllidea, some Proteocephalidea*); and merocercoid, an alacunate form with an invaginated scolex. The final host is infected by eating an intermediate host that harbors metacestodes. The scolex of the metacestode attaches to the intestinal wall of the final host, and the neck of the cestode starts to produce proglottides, thus the strobila is formed [62].

Acanthocephalans

Acanthocephalans, also known as thorny or spiny-headed worms, are exclusively parasitic organisms. These groups of parasites belong to a phylogenetic clade known as Syndermata, with sub-taxa *Acanthocephala and Totatoria* [63], with about 1200 species divided into four classes, namely: *Archiacanthocephala, Eoacanthocephala, Palaeacanthocephala, and Polyacanthocephala* [64]. They are all intestinal parasites of vertebrates, such as fish, amphibians, birds, and mammals. Nearly half of the 1200 species of acanthocephalans are parasites of fish digestive tracts [65].

Acanhocephalans are helminthes belonging to a separate distinct phylum, Acanthocephalan, with three classes divided into about 1200 species, and all are intestinal parasites of vertebrates. Fish, amphibians, birds, and mammals are their major hosts [66]. They are cylindrical in shape, provided with an eversible hooked proboscis in the anterior part, with no digestive system (they absorb nutrients using the whole surface of the body)[67]. They attach to the intestine of fish using the proboscis, which leads to mucosal tissue damage at the site of attachment, resulting in fibroplasia which may extend into muscularis. The fish's absorption efficiency is undoubtedly reduced once the intestinal villi are destroyed [68].

Trematode

Trematodes are divided into two sub-classes: *monogenea* and *digenea*, which are generally referred to as flukes. Small groupings of parasitic trematode species that affect mollusks, fish, and chelonians are members of the *monogeni*a [69]. These parasites are distinguished by a ventral holdfast (attachment organ) that spans the majority of the ventral surface of their bodies and is split into longitudinal rows of independent suckers by an arrangement of loculi (also known as alveoli or rugae) [11]. The Digenea are a much bigger group, with the great majority using mollusks as primary hosts and vertebrates as ultimate hosts. They are distinguished by their sucker-like ventral attachment organ, which generally does not encompass more than half of the body [34].

Monogeneans live on the gills, skin, and fins of fish and other lower aquatic invertebrates. A handful have been seen to infiltrate the rectal cavity, ureter, abdominal cavity, and even the circulatory system. Monogeneans are found in fish all over the world, in both fresh and salt water, and at varied temperatures. The majority of monogeneans are browsers, moving over the body surface and eating on mucus and gill detritus. Monogeneans have a system of hooks on their bodies that allow them to adhere to each other while feeding. Most species are host and location specific, with just one host required to complete a life cycle [70].

Because gills are directly engaged in gas transmission, ion exchange, and the maintenance of acid-base balance in the body, monogenean infection causes high mortality in the fish population. They also produce localized hemorrhages by breaking the attachment point. They feed on the cells of damaged tissue and blood at the same time. More than 100 monogenean families have been discovered in freshwater, brackish water, and marine fish of varying temperatures. *Gyrodactylidae* and *Dactylogyridae* are the most important of these two families since they mostly infest cyprinid fishes, which have a great economic value [71,72]. Monogeneans have direct life cycles, which implies the parasite may replicate without the need for an intermediary host. Adults are hermaphroditic, meaning that they have both male and female reproductive organs. Oviparous monogenes (*Dactylogyridae*) release eggs into the water column, which hatch and mature before they move on to find a new host [73,74]. Viviparous monogeneas (Gyrodactylidae) produce live larvae that can adhere to the same host as the parent or be taken to another host by the water [75,76].

Pathogenesis and clinical signs: Skin-inhabiting flukes cause freshwater fish to grow drowsy, swim near the surface, seek the pond's edges, and lose their appetite. They may be seen touching the holding facility's bottom or sides (flashing) [77]. Areas of scale loss appear on the skin where the flukes are connected, and a pinkish serous fluid may leak. Respiratory illness is caused by heavy gill infestations. The gills may become bloated and pallid, the respiration rate may increase, and the fish's tolerance for low oxygen levels may decrease. In fish with acute respiratory distress, "piping," or gulping air at the water's surface, may be noticed. A large number of monogeneans on the skin or gills might cause secondary bacterial infection [78,79,80].

Treatment and prevention: Praziquantel (2–5 mg/L in a lengthy bath for 2–3 weeks), hydrogen peroxide (high doses of 300–560 mg/L (ppm) for 10 minutes), and formalin (30 mg/L) are the treatments of choice for monogeneans in both freshwater and marine fishes (ppm). Avoiding parasite introduction into a new system is the best strategy to handle monogeneans. A quarantine protocol can help with this [79].

Ectoparasite of Fish

Parasites may induce a shift in fish species densities and size composition and affect commercially interesting stocks. Ectoparasites are those that live on the outside of the host on the gills, mouth, skin, and fin surfaces. The most important external parasites of fish are protozoa, crustaceans, and monogenic trematodes [81]. Crustaceans, along with insects, arachnids, and many other groups, are members of the phylum Arthropoda; all arthropods have hard exoskeletons or shells, segmented bodies, and jointed limbs. Crustaceans constitute a large group. More than 45,000 species are known in the subphylum crustacean, including crabs, lobsters, crayfish, shrimp, krill, barnacles, copepods, ostracods, etc., inhabiting a wide range of habitats and are free-living, parasitic, or sedentary organisms. Among them, the copepods are dominant. Indeed, many parasitic species have free-living larval stages that are part of the food chain [82,61]. Crustaceans have three body segments, including the head, thorax, and abdomen. These segments are so difficult to distinguish because of the fusion of various parts.

Parasitic crustaceans are an increasingly serious problem in cultured fish and can infect wild populations. Most parasitic crustaceans of fresh water can be seen with the naked eye as they attach to the gills, body, and fins of the host. Small crustaceans or copepods are common parasites on the gills of aquarium and pond fish, where they appear as white spots. The gills become obstructed and the fish die of anoxia [61,83,84]. There are three main groups of parasitic crustaceans affecting commercially important aquaculture species, most of which are external parasites: Branchiura, Copepoda, and Isopoda [85]. Branchuria and isopod parasites are relatively larger in both sexes than copepods [86,87]. Parasitic crustaceans are numerous and have a worldwide distribution in fresh, brackish, and salt waters [88].

Copepod

Ergasilus Copepod

Nearly 30 families of copepods contain parasites that utilize fishes as hosts, and most are found exclusively on fishes. The body form of fish parasites varies from cyclopiform through to highly metamorphic [89]. Male parasitic copepods die after copulation in the preadult stages, so those that are seen attached to fish are generally mature females with distinctive paired egg sacs at the posterior end. Only adult females are found in fish gills, and only a few species of Paraergasilus are found in places other than the gills. The cephalothorax constitutes half or more of the body length. The parasite body part is segmented with a thorax except for the first segment that is fused with the head and abdomen. The second antenna terminal segment in Ergasilus is hooked, and three are clawed in Paraergasilus. Eggs are clustered in a bunch rather than arranged in a signal line [88,90]. Only the female of the Ergasilidae family is parasitic, and she lives on the gills of fish. Males are free-living, and the larval development is protracted and free-living, with three to six stages of nauplii and four to six stages of copepodites (lasting from 10 days to over a month). Gill-attached females lay their eggs in two sacs attached to the genital region. The quantity of eggs (20-100) varies by species, as well as age and metabolic health, as determined by the attachment site on the gills. Temperature affects how long it takes for eggs to hatch; at an ideal ambient temperature, it takes 3-6 days. It's been proven that increased salinity slows larval growth [90,85].

Pathogenesis and clinical signs: Ergasilid females feed on gill tissue and mucus, then generate little erosion foci. Erosion and degradation processes may extend beyond the epithelial lining, causing bronchial blood vessels to become blocked. Irritation causes responsive epithelial hyperplasia, which can spread over wide sections of the gills as infection progresses, resulting in lamellae fusion and embedding, and a reduction in gill respiratory performance. Mechanical injury, petechial bleeding, reduced breathing, epithelial hyperplasia, and anemia accompanying growth retardation can all be caused by heavy infestations. The feeding activity of the copepod causes severe gill injury, which often results in fish mortality [82,88,85].

Diagnosis: Finding a parasite adult female with considerably enlarged second antennae connected to the gills of fish and monitoring clinical signs are used to make the diagnosis [82]. Many ergasilid copepods can be found on the body surface, gills, and bronchial and nasal cavities of a variety of fish, including sea bass, grouper, mullet, pearl spot, and tilapia, where they feed on blood and epithelium [85].

Treatment and control: Ergasilus can be successfully treated for 6 to 9 days using a mixture of 0.5 ppm copper sulfate and 0.2 ppm ferric sulfate. For three weeks, a 3 percent salt dip was followed by a 0.2 percent dip [83]. The most effective strategy of control is to avoid introducing sick fish into lakes and ponds. Parasitic copepods are likely to be reduced by routine disease management techniques such as stocking density reduction and water quality management. It is generally known that a few sick/stressed animals are more prone to infection and carry the majority of parasites [82,88].

Lernaeidae (copepod)

Lernaeidae is the group of copepods that have the rod-shaped, unsegmented or partly segmented parasitic stage of the female that is anchored with the aid of a specialized holdfast organ to the fish skin or buccal mucosa. Larnaeid genera are differentiated from the species lernea based on the morphology of the anchor organs of the parasitic females [82,85]. The parasitic female embeds her anterior end in fish flesh and grows from about 1.5 mm to over 10 mm in length in about a week. Mature females have two egg sacs immediately posterior to the pregenital prominence. Copepodites of lernaeaids attached to gills are readily differentiated from Ergasilid parasitic females by lacking the hook (Spine) type terminal segment of the second antenna [86,85]). Parasitic copepods have a complex life cycle with different larval stages, between each of which is a molt [88]. There are three naupliar stages, five copepod stages, a pre-adult and an adult stage in the life cycle. Both copepods and adult females are found on the same host, suggesting that at least some can complete the life cycle on one host. In cooler climates, there may be only a single generation per year, whereas in warmer climates, the life cycle can be completed in 12 to 14 days [85].

Anchor worm infections produce granulomas or necrotic lesions that are later transformed into fibrotic encapsulation of the fish tissue around the anchor. Their pathogenicity largely depends on their host size, number of parasites, and attachment site preferences. Infection by a single or 2-3 females is very damaging or even deadly to young or small fish in the liver, intestine, or brain [82,85]. The ubiquitous skin *Lernaeids*, such as *L. cyprinacea* and *L. hardingi*, cause severe damage only in the heavy infections that cause hemorrhage and ulceration [91]. Frequent rubbing or "flashing" inflammation on the body of fish causes tiny white, green or red worms in wounds, breathing difficulties and general lethargy; retarded growth, anemia, epithelia hypertrophy, restlessness and death. Major injury is caused by loss of blood and by secondary infection with bacteria, fungi, and other organisms [82].

Diagnosis: Anchor worms can be seen with the naked eye as they protrude from various sites on fishes, and microscopic examination of scrapings from skin, gills, and fins of infected fishes can be done by observing general clinical symptoms [88,82].

Treatment and control: Lernaea is extremely difficult to control because only the free-living larvae are susceptible to treatment [88]. Although control is not easy, some steps can be taken to reduce losses through chemical control, inspection of introduced fish and cleaning the environment once an outbreak has occurred. Hence, prevention is more effective than control. 1% of common salt eliminates larvae in 3 days; 250 ppm of formalin for 30 to 60 minutes. Other chemicals, such as organophosphate and organ halogen insecticides, dipped in potassium permanganate ($KMnO_4$), kill attached female Lernaeaids. Removal of the parasite by hand with forceps may control Lernaeidae infections with careful monitoring of the wound [85].

Branchiura

Argulids are the group of Branchuria. It is also called "fish lice". It comprises a head of five limb-bearing segments and a trunk, divided into a thoracic region carrying four pairs of strong swimming legs, and a short abdomen, comprised of a single bilobed unit (caudal fin). Dorso-ventral flattening and dorsally covered by a rounded or horseshoe-shaped carpace. Ventrally positioned head appendages are developed for attachment [92]. Only one species of Dolops is present in Africa. It differs from Argulus in having the second maxilla armed with a hook rather than a sucker, characteristics of the latter. Chonopeltis are usually the smallest; head appendages are feeble and rudimentary; the mouth tube found in the other Argulids is absent, whereas the cup-like sucker of the second maxilla is distinctly developed. The carpace is reduced in size and width [91].

Twenty-nine endemic species occur in Africa, in fish of diverse families. Argulus africanus and Dolops ranarum are opportunists and occur in diverse fish in all major systems of Africa. Allied species, *A. rhiphidiophorus* and *A. cunningtoni*, replace A. africanus in some East African lakes connected to the upper Nile, and co-exist in others, in part at least, due to later artificial introductions of fish. Argulus species are commonly found in aquariums, ponds, and wild fish. The rest, including members of the genus Chonopeltis, are host-specific and limited to a single water system [91]. Species of *Argulus* and *Dolops ranarum* are parasitic throughout life, but leave the host to moult or lay eggs, and during this process, they will also change hosts. Both males and females may survive free living for as long as 15 days. *A. africanus, A. cunningtoni, A. rhiphidiophorus*, and *D. ranarum* have a preference for smooth-skinned fish (siluriforms and lung fish). The same species may, however, infect buccal and opercular mucosal integuments of scaly fish, notably cichlids [90].

Males transfer sperm directly to females in most brachyurans using a variety of modified structures on the third and fourth thoracic legs [92]. Mating takes place while they are free-swimming [90]. In freshwater species, after taking a meal, a mature female Argulus will leave its host and begin to lay eggs in rows on any hard, submerged surface. These eggs hatch into free-swimming larvae. The larvae function as a dispersal phase and molt into the second stage. The first larval stage lasts about six days, and moults occur at intervals until maturity. Branchiurans are parasitic from the second larval stage onwards, but appear to leave the host and then find a new host at intervals throughout development [92].

Pathogenesis and clinical signs: Brachyurans damage the fish directly by extracting blood and vital tissue fluids from the host with their modified mouth parts. The mode of feeding of Argulus involves the secretion and injection of relatively large quantities of digestive fluids which are toxic to the fish. A single fish lice sting can kill a small fish [92]. Feeding sites become hemorrhagic ulcerated and provide access to secondary infections by other pathogens. Mucus is secreted when skin, fins, and gills become infected. Persistent irritation caused by heavy infections may affect fish appetite with resulting anorexia and cessation of growth; scratch itself against rocks or repeatedly jump out of the water in an effort to dislodge the parasites; erratic swimming [93].

Diagnosis: It is possible to see the parasites with the naked eye, which range in length from a few millimeters to about 30 mm, and microscopically observe the clinical signs like hemorrhages and ulcerative skin and gills [92,93]. The treatment and control of Argulus infestations includes the use of common chemicals such as salt (NaCl) and other common chemicals used in experimentation, including formaldehyde, potassium permanganate (2-5 mg/l bath) and formalin. The most effective treatment against argulosis is organophosphates [94,91,93]. Individual parasites can be removed from fish with forceps, but this does not eliminate parasites in the environment. To control Argulus, remove the submerged vegetation. A wooden lattice placed in the pond will serve as an artificial substrate to deposit its eggs, which can be removed at intervals to kill the eggs. The keys to prevention are avoidance and quarantine [95,93].

Isopoda

Isopoda are the largest crustaceans found on fish (20-50 mm long). The body consists of three regions; the head is unsegmented and bears two pairs of antennae, a pair of variable sized eyes, and a mouth. A second region, the peraeon, of 7 segments, each with a pair of legs (peraeopods), and a third region, the pleaon, of 6 segments with pairs of pleopods, except the last, which together with biramous uropods forms a swimming tail pleotelson [90]. Most parasitic isopods are ectoparasites, which inhabit the warmer seas and are typically marine. There are three major groups of isopods, including cymothoids, epicaridians, and gnathiids. Cymothoids are parasites of fish, both as immature forms and as adults. Epicaridians are parasites of crustaceans as immatures and adults. Gnathiids are larval parasites of fish, the adults being free-living and non-feeding. Genetically, the cymothoids and epicaridians appear to be closely related, whereas the gnathiids appear to have evolved from different isopod lines [92,96].

Parasitic isopods are typically marine, and usually inhabit the warmer seas, and infections have been reported in euryhaline fish in estuaries. A few species of Cymothiod isopods (Lironeca spp.) occur in African freshwater fish (apparently as marine relics) in the Congo basin (in cichlids, a clupeid and a citharinid). Opportunistic euryhaline cymothoids of several families and genera infect farmed fish in Southeast Asia, including cultured tilapia [92,90]. The cymothoidae life cycle involves only one host (the homoxenic cycle), and it attaches to fish early in life and passes through a male stage before becoming female. The presence of a mature female prevents male stage specimens from further development [92,96,97,90]. Both males and females remain permanently attached to the fish. Egg and larval development take place in a special brood-pouch on the female's ventrum. Another group, the gnathiid isopods, is marine and only parasitic during the larval stage [97,90].

Pathogenesis and clinical signs: Cymothoidae are blood-feeding Several species settle in the buccal cavity of fishothers, living in the gill chamber or on the body surface, including the fins. Cymothoa spp. causes serious problems in fishes kept in captivity or cages. The damage caused by them resembles that of other copepods, but the most serious eject of isopod infection is the destruction of host tissue resulting from the pressure of the parasites' body [96,97,98]. The degree of damage to fish varies with the site of attachment and ratio between the isopod and the host. Lesion to the integument causes hyperplasia, or desquamation, and later on, dermal inflammation and necrosis. The parasite can also impede the opercular respiratory movements. As cymothoids penetrate the skin with their pereopods and mouth parts, and the tissue inhabiting forms maintains a small opening to the outside, secondary infections occur. The wounds they cause may provide entry points for microbial diseases [90,97].

Diagnosis: Grossly observed parasites on the skin, mouth, or gill chamber with associated lesions. The hemorrhagic and necrotic head tissues are evident when observing the fish in their cage. When the sick fish are removed from the water, several isopod larvae may be seen in their buccal and gill cavities and/or on the skin near the opercula [86].

Treatment and control: No specific control or therapeutic measures against isopods have been in practice except the manual removal of the parasite and by implementing optimum management practices during culture as infection by the planktonic phase is the common feature. However, chemical treatment for cage culture is not practical; Trichlorfon (Dipterex) at a concentration of 0.5-0.75 ppm for 24 hours is recommended for pond treatment [99,86,88].

Protozoal disease

Protozoans are single-celled organisms found predominantly in the aquatic environment as free-living organisms. Fish are vulnerable to protozoa because they have the potential to proliferate on and within their hosts [100]. Depending on the species, protozoans can be either ectoparasites or endoparasites. The protozoa ectoparasites that are typically seen in cultured fish can feed on the top layer of the skin [43,101]. They have a direct life cycle and primarily reproduce through binary fission; however, some species have a cyst form that is independent 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. There are three major groups to consider they are ciliates, flagellates, and amoebae [101,23].

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 that cause mortalities in a number of wild and farmed fishes. Ciliates 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 [101]. *Ichthyophthirius multifiliis*, commonly 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 [102,103]. Ich infection can occur at any stage of fish development, including fry, fingerling, table size, and 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 [104]. *Ichthyophthirius multifiliis* is spherical in shape, and the cilia are evenly distributed over the whole surface. The defining characteristics 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 that allows a rapid intensification of infection. The direct life cycle of the parasite consists of three stages: infective theront, obligate, fish associate trophont, and water-borne reproductive tom. All stages are ciliated and motile [42].

Naturally occurring epizootic outbreaks of *ichthyophthiriasis*, also known as ich or white spot disease, have occurred in farm raised fish on most continents. 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 [42]. The parasite invades the epithelial tissue of gills, skin, or fins, leaving a small wound and a visible white spot or nodule where each parasite encysts [102]. 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 the death of the fish [102]. Ichthyobodiasis is caused by a flagellated protozoan of the genus *Ichthyobodo*, formally known as Costia. *Ichthyobodosis* is an important parasitic disease that has caused severe loss among ornamental and farmed fish worldwide for more than a century. The disease is caused by heavy infections on skin and gills by parasitic flagellates belonging to the genus Ichthyobodo.

Table 1: The most common protozoal disease of fish.

Disease	Etiology	Location	Clinical signs	Treatment	Reference
Ich, white spot disease	Ichthyophthrius multifilis	Embedded in skin or gill of fish	Irritation,small white nodules Infected fish fall to bottom,salt like specks on body,excessive slime,difficult breathing,loss of appetite	Raising temperature to 80° F, quinine hydrochloride at 30 mg per liter.	Dickerson 2006; Dickerson and Buchmann, 2011; Durborow *et al.,* 2000
Trichodiniasis	Trichodinia	Attach to gills	Lethargy,scratching against object, breathing at surface, hanging at surface,clamped fin,darker colour of body,excess mucus	Malachite green,salt bath,formalin, acriflavin, methylene blue	Iswari *et al*., 2020; Smith and Schwarz, 2009
Coastiasis (ichyobodiasis)	Ichythyobodo or costia	Skin and gills	Lethargy,clamped fins,rubbing and flashing skin,milky cloudiness on skin,	Acrifilavine,copper,salt bath,raising water temperature to 80° - 83° F	Idaksen, 2013
Chilodonellosis	Chilodonella	Skin,head and dorsal fin	Opaqueness of skin, gills are attacked and destroyed,they hang at the pond surface and gasp for air	Malachite green,formalin, potassium permanganate,salt bath	

Conclusion and recommendations

Fish have crucial importance in livelihood food security that provides both food consumption and income in developing country. Though so many factors effect on the fish production that include infectious and non-infectious disease. Among non-infectious disease parasitic infestation is the common problems that lead production loss. The parasitic infestation of fish may cause decreasing growth rates, spoilage of fish, lowering quality and quantity of fish and cause rejection of fish products. The most common parasite of fish includes helminths, protozoa and crustaceans. Helminth parasite are the most common in parasite of fish that cause harmful on fish. The diagnosis of fish parasite almost carried out at necropsy due to the parasite live inside and on the surface of fish organs. The diagnosis also carried out at lab level on the presence of eggs in feces of fish. The health management of fish is based on the diagnosis that identify the species or genus of parasites. Prevention and control are the most common health management approach against the infectious and non-infectious diseases, treatment also needed but not mandator. The biosecurity is needed in the control of parasitic infection of fish that carried out on the sanitation of point, isolation of infected fish, giving the treatment for the diagnosed or culling infected species to avoid some intracellular parasites. The researcher has not been conducted on the health management of fish in Ethiopia rather than the prevalence and risk factors. To conclude that, fish is susceptible to parasitic infection the same to that of large animals and become diseased. However, the fishers and other else didn't focused on the detailed risk factor, health management and disease of fish. Therefore, the base on the above-mentioned information the following recommendation should be forwarded.

✓ The most common parasitic disease in developing country should be identified at laboratory level

✓ The health management of fish have to be conducted in freshwater fish

✓ The government sector should have to give the attention on the production of fish

✓ The detailed research should be conducted on the parasitic disease of fish

✓ The awareness on the zoonotic disease of fish should be given for the communities

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