Sohag Journal of Sciences
*An International Journal*

**Review Article**

# Fish's Crustacean Parasites: Types, Prevalence, Clinical signs, and Control

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Received: 19 March. 2022, Revised: 13 April. 2022, Accepted: 27 April. 2022.
Published online: 1 May 2022

**Abstract:** Crustaceans during a parasitism relationship with fish cause biological disruption and diseases to the hosting fish that threaten their life. Several crustacean groups were reported to parasitize different fish species as definitive hosts. Copepods, Isopods, and Branchiura are the major fish parasitic groups under the crustacea. They are mainly ectoparasites and occasionally, the small and microscopic members can infest the internal organs of their fish hosts. The infected fish are suffering from serious clinical signs and the infested organs are usually suffering from severe pathological disruptions and lesions. Treatment is taking place by several chemical and biological facilities. Here in the current article, the major crustaceans that parasitize on fish are reviewed by describing their corresponding harms to the hosting fish. Factors affecting the prevalence of the crustacean parasites and some of their hazardous effects on the infected fish were considered. In addition, trials for the chemical and biological control of the crustacean infestations are summarized.

**Keywords**: Crustacea – Fish Diseases – Parasites – Prevalence – Treatment.

## 1 Introduction

Fish diseases are infectious or non-infectious; non-infectious diseases are called "environmental diseases" and are caused by abiotic factors, while infectious diseases are caused by multiple biotic factors, including viruses, bacteria, fungi, and parasites of various animal groups [1]. Parasitic diseases of fish are infectious and can widely spread between several hosts, especially in polluted environments; therefore, parasites are usually considered biological indicators for environmental contamination [2]. The parasites are of two types, "obligate", which need hosts for their survival and/or reproduction, or "opportunistic", which are free-living and become parasitic on the weak hosts in what is known as opportunistic parasitism [3].

Parasitism is an unfair relationship between two living organisms, one benefits and the other suffers. Parasitic infections of fish have direct and indirect effects on their production, as parasitism influences the hosts' growth and reproduction ability and increases the mortality rates among the infected fish causing a significant economic losses for the aquaculture industry [4]. Ecto-parasitism is one strategy for that unfair relation in which the parasite attacks the outside organs of the definitive host, including the integumentary system and body openings, which usually affect the hosts' physiology, behavior, performance, energetics, and even morphology [5]. Fish are suffering from different kinds of ectoparasites, which are related to a wide range of animal groups from the Protozoa such as *Trichodina* sp. [6, 7] up to the Chordata such as Sea lamprey (*Petromyzon* sp.) [8, 9]. Occasionally, the microscopic crustaceans can endo-parasitize their hosts and infest their internal organs.

Several crustacean species have evolved to be closely associated with and dependent on other animals for keeping survival, which, therefore, propagated disease problems [2]. All fish species of all water ecosystems worldwide; the fresh, brackish, and marine water are susceptible to being infested with these crustacean parasites [1, 10, 11]. The ectoparasitic crustaceans attack fish integument, gills, nostrils, and/or oral cavity, whereas the endo-parasitic crustaceans stay in the bloodstream or attack the internal organs such as the branchial and cardiac tissues [4, 12, 13]. Furthermore, crustacea can infest different life stages of fish and can easily adapt to their hosts, this infestation can be in the form of single, double, or multiple parasitisms on a single fish, which cause serious disease outbreaks in the aquaculture [2, 14]. Moreover, parasitic crustaceans serve as vectors of other microbial pathogenic organisms such as viruses and blood parasites [15]. Therefore, fish parasitism is usually associated with secondary infectious diseases, which doubles the severity of the infestation, and the suffering of the infected fish [2].

Numerous crustacean species are known to parasitize fish; all are falling under the three major groups Copepods, Isopods, and, Branchiura [16 - 18]. Considerable bits of knowledge about the crustaceans parasitizing the fish and their prevalence, pathogenesis, and control are reviewed in the current article.

## Major Crustacean Parasites for Fish

Copepoda, Branchiura, Isopoda, Amphipoda, Barnacles, and Ostracoda, are known as the main groups comprising the parasitic crustacean classes [13, 19]. The three major groups Copepoda, Isopoda, and Branchiura comprise the crustacean

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parasites for fish. These groups are either ecto- or endo-parasites, in addition, Lernaeidae (Copepoda) is the only family comprising mesoparasites on fish worldwide [13]. Ostracoda might occasionally attach inside fish tissues, which were damaged by other isopod parasites, and they can feed on the fish's mucus and skin debris while they are not parasites and can not strike serious hazard to the hosting fish [13]. However, Bennett et al. [20] reported in an early study the parasitism of an ostracod (*Sheina orri*) on the gills of a shark; nevertheless, they did not assure its ingestion of the shark tissue.

## I. Order: Copepoda

Copepods are the most common and prevalent parasitic group on fish [21]. Unlike the generous sized Isopoda and Branchiura, Copepoda are small to microscopic-sized crustacean parasites that were free-living during the early life stages, then the adults, in most cases, become fish pathogenic and leave high mortalities in fish farms [1, 16, 18]. Several copepod members were reported to parasitize numerous fish species worldwide [22, 23]. Adults of the genus *Caligus* (order Siphonostomatoida) are ectoparasites and known as fish's Sea lice (Sea fish lice), while some of their larval stages are free-living crustaceans (Figure 1) [13].

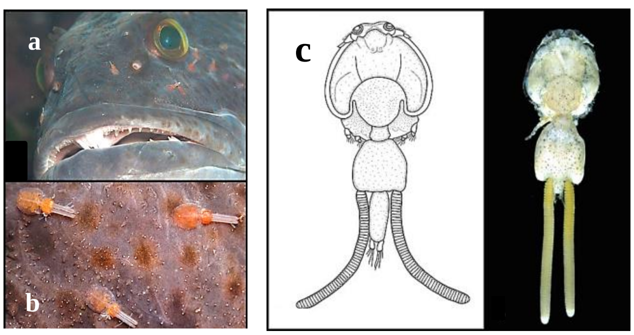


**Figure 1.** Sea lice *Caligus* sp. (Copepoda) ectoparasitic infection on a fish skin surface. (a) Females Sea lice parasitizing the skin surface of a fish head; (b) close-up of 3 parasites attaching to the skin; (c) Sea lice morphology [13, 24].

The first record of the parasitic copepod *Caligus chiastos* was in 2009, when it was isolated from the body surface and gill cavities of marine fish cultured in floating cages in Malaysia [25]. Some adult male copepods such as *Ergasilus* sp. are free-living and the females only can parasitize on fish [26]. *Salmincola* spp. were reported to ecto-parasitize wild and cultured salmonids [21]. *Learnea* spp. and *Ergasilus* spp. are other common fish lice copepods that were frequently reported to infest the external bodies of several freshwater fish collected from different aquaculture facilities [27].

## II. Order: Isopoda

Crustacean isopods include three main parasitic groups, cymothoids, epicaridians, and gnathiids. Adults cymothoids only parasitize fish, while the gnathiids larvae parasitize fish and their adults are free-living, whereas epicaridians parasitize on other crustacea [3]. Like all parasites, some isopods are obligate parasites, whereas some others are opportunistic. Several cymothoids isopods were reported to infect fish larvae as well as adults [28]. They infest different sites of the host such as body surface and cavities, or anchor inside and feed on its blood, or even attack the rudimentary tongue (tongue replacement or tongue-biter parasite *Cerathothoa famosa*) (Figure 2) [12, 29, 30]. Moreover, owing to its tinny size, isopods may anchor the host's bodies and endo-parasitize their internal organs [13].

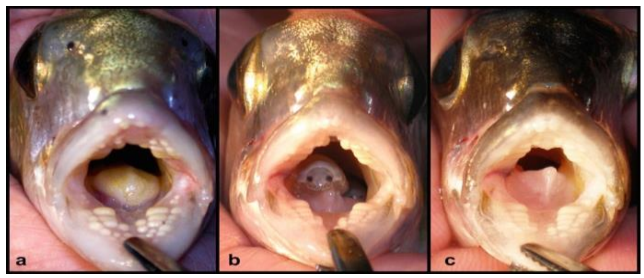


**Figure 2.** Isopoda (Cymothoid) parasitism on fish; tongue-biter infestation. (a) Noninfected fish tongue; (b) Fish infested with the tongue replacement parasite; (c) Damaged and stunted tongue of the infested fish caused by the parasite [13, 30].

## III. Order: Branchiura

Branchiura has several fish parasitic groups, which were widely studied from their sexual size dimorphism [31] up to their pathogenicity to fish and frogs [32]. *Argulus* sp. (Figure 3) is one of the most common Branchiura parasites on fish and several species, which are commonly named as fish louse or fish lice [19, 33].

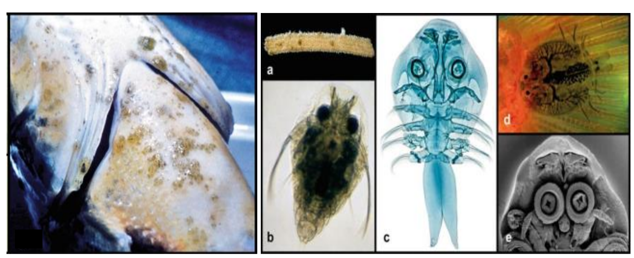


**Figure 3.** Fish infestation with *Argulus spp.* (Branchiura), the causative agent of argulosis. (a) Egg rows; (b) free-swimming larva; (c) ventral view of an adult male having swimming appendages; (d) adult female on the gill filaments of a hosting fish; (e) Enlarged head of *Argulus foliaceus* showing its paired maxillulary suckers [13].

More than 100 different species of *Argulus* are distributed worldwide and can infest the freshwater and marine fish species, in wild and pond-raised habitats; and some of them can also infest frogs and toads [32, 34 - 40].

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## Prevalence of the Crustacean Parasitism and Fish Susceptibility

In general, all the fresh, brackish, and marine water species of the cultured, wild, and feral fish are susceptible to crustacean parasitism, which is highly abundant in the polluted environments [41 - 44]. However, fish age and size are factors affecting their susceptibility to parasitic infections. The infection with *Argulus foliaceus* and *Ergasilus sieboldin* is more prevalent in big-sized than the smaller fish [1]. Notably, the exposure time is the key factor for the parasites' aggregation on their hosts and diseases generation [45]. In some extent, the prevalence is varying between the infested sites of the same fish (Figure 4) [26].

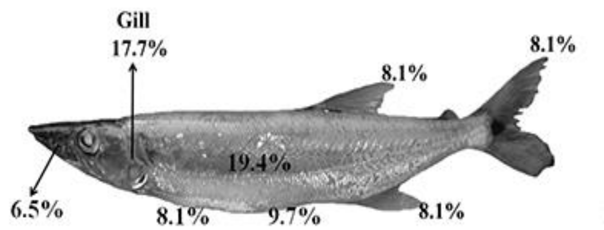


**Figure 4.** Prevalence pattern of a crustacean species parasitizing different sites on a fish species from eastern Amazon, northern Brazil [26].

Ectoparasitism is prevalent in a variety of aquatic habitats and depths; however, the diversity of both the hosts and the ectoparasites decline in the deep-sea communities; in addition, ectoparasites are often detached during the collection of their hosts, which hinders their proper investigation [46]. In addition, illumination and the slow swimming speed in the dark are factors influencing the fish's susceptibility to the parasitic infestations [47].
Parasitic infestations and parasites development are induced by the higher water temperatures; therefore, their seasonal prevalence is most often in Summer [44]. On contrary, egg hatching of the crustacean parasites is routinely going at a much slower rate throughout the summer and accelerates in the winter [48]. Higher egg prevalence of the Branchiura *Argulus coregoni* was reported in the Summer season and the highest egg clutching was found on the deepest stones [48]. Isopod crustacean parasites were reported as obligate ectoparasites for fresh and marine water fish, with higher prevalence in warm marine water [30, 49]. The copepod *Lernaea cyprinecea* was recorded at higher seasonal prevalence in summer, while they did not be observed in the winter [27]. Fish louse parasitizes the wild and farmed fish and its harm is depending on the water temperature [50].

## Clinical signs

As a defense mechanism, the infested fish have shown a variety of clinical signs. Several investigations referred to several common clinical signs characterizing the crustacean ectoparasites. Severe infestation with Sea lice (*Lepeophtheirus* sp. and *Caligus* sp.) cause osmoregulatory failure and secondary infections, which lead to fish death [42]. The hosting fish secret excess mucus from the skin and gills, and the suffering fish frubs its body against hard objects to dislodge the irritating ectoparasites [19, 51]. Skin redness and opacity, excessive mucus secretion, and rapid operculum movements were the main signs characterizing argulosis [1]. Swelling of the attachment sites associated with erythematous and hemorrhagic lesions are the common signs of Copepoda and Branchiora infestations [19]. Skin damage and inflammations were reported at the anchor worm attaching areas [44]. Obstructed gills and anoxia were also reported as signs of crustacean ectoparasites [18]. Severe tissue destruction and dysfunction reaching fish tongue replacement are common signs of the Isopoda infestation [3, 27].
It is worth mentioning that ectoparasites potentially alter the host skin microbiota and this is associted with the repeatedly changing of the hosting fish or site. This inflicts skin damage and possibly increases the host susceptibility for secondary infections [52, 53]. Recently, the microbiota from the copepod *Lernaea cyprinacea* were found to be significantly different from the normal microbial communities of intact skin either from infested or un-infested fish [53]. This indicates changing the skin microbiota upon skin ulceration by the crustacian infestation. Moreover, crustacean parasites may alter the proteome and transcriptome aspects of fish tissues; therefore, deep molecular investigations on proteomic and transcriptomic levels are required to understand the host-parasite interactions [54, 55].

## Treatment and Control

Management of fish health (such as providing prophylactics in feed) and environment (such as keeping water and feed quality, and avoidance pond overstocking, drying, and liming) is a critical issue to avoid parasitic infections in aquaculture, where prevention of fish diseases is always having the priority over treatment [16, 18]. Early treatment and accurate quesionnaire of the pond case history are quite important for effective feedback [18]. In addition, omics technologies are highly implicated in antiparasitic vaccines development; however, this is still an emerging avenue for fish parasitology [56].

### I. Chemotherapeutic Control

Several chemical compounds are frequently used in aquaculture chemotherapy, either individually or in combination. In an early study chemotherapeutic reagents, including organophosphates, pyrethrin/pyrethroid compounds, avermectins, benzoylphenyl Urea, and Hydrogen peroxide (oxidizing agent) were reported for sea lice control [42, 57]. Sodium chloride, Dipterex, and Lime were used to overcome several parasites; and Lime, Potassium permanganate, and Sumithion were effective reagents overcoming argulosis in fish farms [16]. Abowei et al. [19] controlled argulosis with an indefinite application of low doses (0.12 and 0.25 mg/L) of "Benzene hexachloride". Notably, the recent trend is to use natural therapeutics with high delivery and biosafety, especially for controlling endo-parasitic infestations [58]. Nowadays, the recent trend is to use biotherapeutics with high delivery, efficiency, and biosafety, especially for controlling the endo-parasitic infections, to avoid any possible side effects may harm the fish or the environment [58]. Recently, bionanotechnology is highly implicated in fish medicine for several biotherapeutic applications [59 - 61]; however, more investigations in this emerging field are still needed.

### II. Biological Control

During the outbreak of fish diseases, it is preferable to replace chemotherapy associated with harmful side effects on fish and their consumers with manual strategies such as comprehensive programs for fish health and pond management, and quarantine [18]. The common substitution strategy for controlling the crustacean parasites is biological control by using cleaning symbionts. Therefore, some aquatic animals, probably other fish species “cleaner fish”, are commonly used for the parasites’ biological control in aquaculture and were promising for controlling the crustacean ectoparasites. Sourcing of wrasse fish in the farms is recommended, especially during the first year of its production cycle, for fish health hygiene and crustacean parasites control [62, 63]. It was reported that parasites on wrasse aren’t a major threat to the cultured fish as they are specific to wrasse and/or require an invertebrate host to complete the life cycle [64]. In early studies, a successful symbiosis cleaning strategy was reported by two species of wrasse, goldsenny (*Ctenolabrus rupestris*) and rock cook (*Centrolabrus exoletus*) for delousing of the farmed Atlantic salmon (smolt) with considering the infestation pressure quantification and wrasse/salmon ratios [65, 66]. Skiftesvik et al. [67] used the cultured vs. wild Ballan wrasse (*Labrus bergylta*) for the Atlantic salmon delousing. Similarly, lumpfish (*Cyclopterus lumpus* L.) was used for the biological control of sea lice (*Lepeophtheirus salmonis* Krøyer) infestation in Atlantic salmon intensive farms [68].

## 2 Conclusion

Crustacean parasites are a serious threat to the aquaculture industry. They are worldwide spread in all ecosystems, with a higher prevalence in the warm seasons during higher temperatures. Water pollution, temperature, illumination, and depth, as well as fish overstocking, age, size, and swimming speed are the main factors affecting the prevalence of crustacean parasitism on fish. In addition, the time of exposure to the parasites influences the severity of the infestation. Crustacean parasitism causes severe damage and tissue dysfunctions for the hosting fish, which may kill all the infected population. Overcoming the crustacean parasites is available using therapeutics as well as biological control strategies. However, biotherapeutics and biological control strategies are highly recommended for the environment’s safety.

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