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Review

Prevalence of fish lice, *Argulus* (Crustacea: Branchiura) in freshwater and two ornamental fishes of Iran

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Abstract
Farming and trading of aquarium fish has been considered a popular pastime in the world. Most of Iran's aquarium fish are imported from Asian countries including Indonesia, Malaysia, Thailand and Vietnam. Fish lice (*Argulus*) is known as one of the most important and common ectoparasites in ornamental fish. Reports indicate that these parasites have been observed in ornamental fish imported to Iran (e.g goldfish *Carassius auratus* and koi carp *Cyprinus carpio*). Today, due to mismanagement of some ornamental fish breeding centres in Iran, aquarium fish species such as goldfish may have escaped into the natural waters which increase the risk of transmitting pathogens to native fish. The present work was performed to investigate the outbreak of an ectoparasite *Argulus* in two ornamental fish of Iran and also to evaluate the possibility of transmission of *Argulus* to inland freshwater fishes of Iran.

Keywords: aquarium fish; *Argulus foliaceus*; ectoparasite; goldfish; koi carp

1 | INTRODUCTION

In recent decades, keeping aquarium fish has become one of the most popular human pastimes. This industry is a cheap and economical trade that does not require much capital, so that some countries, especially East Asian countries, benefit from it and export their products to many other countries, such as Iran (Radkhah and Eagderi 2018; FAO 2022). Therefore, the ornamental fish farming industry can be considered a special economic opportunity.

Parasitic infections have been raised as one of the most important problems in the aquaculture sector (Radkhah 2017) that can lead to reduced growth and vital activity of the fish and even its death. The outbreak of ectoparasites not only directly leads to the death of fish, but also impairs their growth and reproduction and predisposes them to bacterial and fungal infections (Pulkkinen *et al.* 2010; Lafferty *et al.* 2015; Assefa and Abunna 2018). The role of fish imported to the country in the spread of parasitic infections is unclear. However, workshop observations indicate the presence of different parasitic species in some imported fish, which can also transmit parasitic infections to inland freshwater fish (Salgado-Maldonado *et al.* 2020).

Fish lice (Crustacea: Argulidae), as an important group of ectoparasites, are found in a wide range of fish species and amphibians (Wafer *et al.* 2007; Poly 2008). These parasites are harmful and limiting factors in the breeding of ornamental fish (Khodadadi *et al.* 2013). Fish lice are of special economic importance because they cause instability, discoloration, deformation of the body, as well as reduced growth and body weight of fish (Mirzaei and Khovand 2015; Shinn *et al.* 2015). Given that ornamental fish pathogens are spreading rapidly around the world due to their commercial benefits, hence, control of infectious diseases of aquarium fish is very im-

portant for risk analysis and precautionary measures (Jalali 1997; Radkhah 2017).

Due to the fact that Iranian ornamental fish are mainly imported from Asian countries such as Malaysia, Thailand, Indonesia and Vietnam (Radkhah and Eagderi 2018), so it is possible to transfer parasitic species, especially *Argulus*, to the country (Radkhah 2017). Because many of these ornamental fish are inadvertently released into the wild by locals (Radkhah *et al.* 2017), it is also possible to transmit these parasitic agents to natural ecosystems and to spread the disease to endemic fish (Guerrero 2014). Given the importance of endemic fish, the prevalence of parasitic species can be considered a serious threat to the population of this group of fish. Therefore, the present work aimed to investigate the biological characteristics of the genus *Argulus* and the outbreak of this parasite in aquarium fish and inland freshwater fishes of Iran.

2 | METHODOLOGY

This narrative review study has examined the outbreak of *Argulus* parasite in ornamental and freshwater fishes of Iran by examining library sources, articles, books as well as authoritative scientific websites. For this purpose, the keywords including "Argulus", "ectoparasite", "Iranian ornamental fish", "inland freshwater fishes of Iran", "goldfish" and "koi carp" were used for search in scientific engines such as Google Scholar, ResearchGate, PubMed, National Center for Biotechnology Information (NCBI), ScienceDirect, Directory of Open Access Journals (DOAJ) and etc. In the first stage of the search, about 50 references were collected, which after evaluation and refinement, about 40 references were selected as valid sources related to the research topic.

In the present paper, first, the biological and ecological characteristics of *Argulus* genus were investigated. Then, the outbreak of this parasite in aquarium fish and inland freshwater fishes of Iran were discussed, respectively. Finally, the necessary recommendations were provided to prevent the widespread and rapid spread of this ectoparasite in fish.

3 | ARGULUS

The genus *Argulus*, also known as the fish lice, is a group of crustacean ectoparasites found in many aquatic organisms. These parasitic species are extensively adaptable and can live in marine habitats and freshwater ecosystems (Boxshall 2015). *Argulus* species, on the other hand, are very strong swimmers and are easily transmitted among many hosts (Boxshall 2015; Radkhah 2017). The ease of transfer of *Argulus* species and their high adaptability can be considered a potential threat to natural systems and endemic fish.

Argulus parasites are morphologically broad, oval, and flat on both sides (Radkhah 2017) covered by chitosan carapace (Figure 1). They have a part called the maxilla, which usually acts as a powerful suctorial organ and is adapted for suction during feeding (Poly 2005). *Argulus* parasites have thoracic appendages that are used to move when joining a host (Wafer *et al.* 2015). These parasites are located on the surface of the skin and use its internal fluids (Hakalahti-Siren *et al.* 2008).

The total length of adult parasites is between a few mm to more than 30 mm (Boxshall 2015). Of course, females are more likely to grow up than males (Yoshizawa 2021). Significant differences between males and females include the occurrence of a pair of testes in the male abdomen and a pair of spermathecae in the female abdomen (Walker 2008). The mode of reproduction of *Argulus* parasite is also very interesting. The mating process of these parasites takes place on host animals such as fish, after which the female parasites are released from the host to lay eggs (Figure 1) and attach to various objects such as rocks and plants with adhesives (Petty and Francis-Floyd 2016). The eggs are often located in the thorax of females, and in some species are also present in the thoracic region and at the corners of the carapace (Radkhah 2017). About 173 species of the Argulidae family have been described, which are divided into six genera. Important species of the genus *Argulus* include *Argulus foliaceus*, *A. japonicus*, *A. coregoni*, *A. africanus* and *A. americanus* (Boxshall 2015; Radkhah 2017).

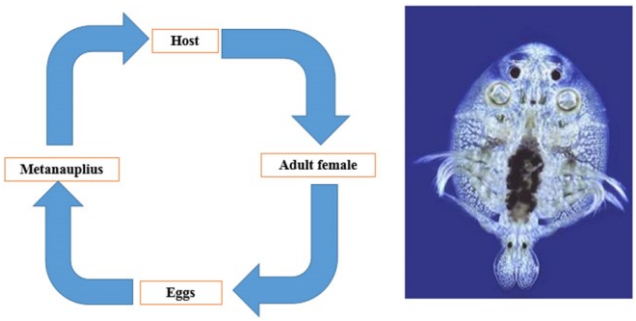

FIGURE 1 *Argulus* and its life cycle (modified from Walker 2008; TNeutron 2021).

4 | PREVALENCE IN ORNAMENTAL FISH SPECIES OF IRAN

Sometimes parasitic infections can cause fish deaths and consequently impose significant economic losses to breeders (Cable *et al.* 2017). Fluctuations in environmental variables such as temperature, salinity, pH, water depth and density affect the incidence of parasitic diseases in fish. Contamination from food and faecal debris can also play an important role in the prevalence of parasitic diseases, as it makes the breeding environment a suitable place for parasites to grow (Suleiman and Al-Harbi 2016). Parasites can exert their effects through various methods such as stimulation, wounding, damage or atrophy of tissues and blockage of arteries and vessels (Assefa and Abunna 2018).

Among ornamental fish, *Carassius auratus*, *Cyprinus carpio*, *Poecilia reticulata* and *P. sphenops* were reported to have the highest incidence of parasitic infections (Radkhah 2017). A survey on the outbreak and abundance of parasites in aquarium fish have shown that *Lernaea* is the most prevalent parasite, followed by Argulus, *Ichthyophthriius*, *Trichodina*, *Heteropolaria*, *Bothriocephalus*, *Dactylogyrus* and *Gyrodactilus* (Chidambaram 2009).

4.1 Goldfish (*Carassius auratus* Linnaeus, 1758)

Goldfish is one of the most popular carp species traded in more than 100 countries (Maceda-Veiga *et al.* 2013; Trujillo-González *et al.* 2018). Trujillo-González *et al.* (2018) confirmed that at least 192 parasites have been reported in goldfish since the 19th century. These results indicate that this fish species is highly susceptible to parasitic infections (Figure 2). Therefore, due to the fact that goldfish is widely traded, it needs more care during breeding.

Noaman *et al.* (2010) were the first researchers to record the *Argulus* parasite in goldfish from Iran. They cited sudden swimming and poor growth as symptoms of parasitic infection in fish. In another study, Rasouli *et al.* (2012) focused on parasitic infections of goldfish inhabiting the water resources of West Azerbaijan province. They stated that *Argulus* was present in 76% of the total fish samples. Examination of this value shows that *Argulus* sp. has a very high prevalence in Aras River fish, which is considered one of the important river ecosystems in West Azerbaijan. Moshaveri-Nia (2016) has observed ectoparasites on different species of fish (e.g. koi carp *C. caprio*, goldfish *C. auratus* and fire eel *Mastacembelus erythrotaenia*) and identified two species of *Argulus* including *A. coregoni* and *A. japonicus*). In another study, Khodadadi *et al.* (2013) examined the frequency of goldfish ectoparasites in Urmia breeding centres. They stated that the parasitic species *A. foliaceus* has a significant frequency in goldfish.

A review of literature showed that *Argulus* have also been identified in most areas where fish are present. Therefore, the prevalence of *Argulus* in this aquarium fish is very high. In other words, this indicates that the goldfish is a very good host for the growth, reproduction and transmission of *Argulus* species.

4.2 Koi carp (*Cyprinus carpio* Linnaeus, 1758)

Mirzaei and Khovand (2015), who studied the outbreak of *Argulus foliaceus* in koi carp in Iran, reported that 7% of the total fish specimens were infected with the parasite. This study showed that koi carp can be a potential factor for hosting and transmission of *Argulus* parasite in Iranian inland waters. Unfortunately, with the release of goldfish and koi carp by local people in natural ecosystems, it is possible to transmit the parasite to native fish.

Kismiyati *et al.* (2017) investigated the effect of the ectoparasite, *Argulus japonicas*, on koi carp in Central Java, Indonesia. According to their findings, the prevalence of *A. japonicas* was 57% in goldfish and 65% in koi carp. Kismiyati *et al.* (2017) acknowledged that the degree of contamination is very high in goldfish and moderate in koi carp. These results indicate that the prevalence of *Argulus* is lower in goldfish, but its level of infection is very high and, consequently, its side effects are more severe. The presence of this parasite causes histopathological changes in host fish that cause skin erosion, epithelial cells and cell inflammation (Figure 3).

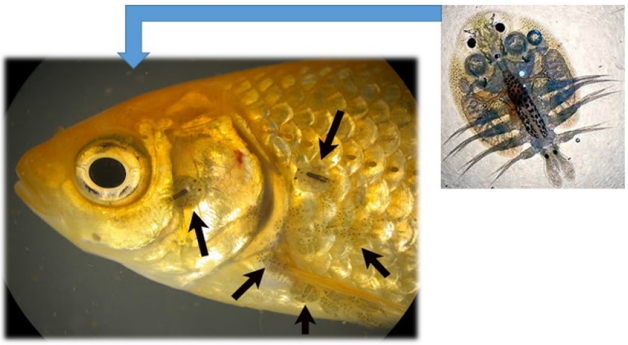

FIGURE 2 Presence of *Argulus* parasite on the skin and gills of goldfish (*Carassius auratus*) (modified from Yoshizawa 2021).

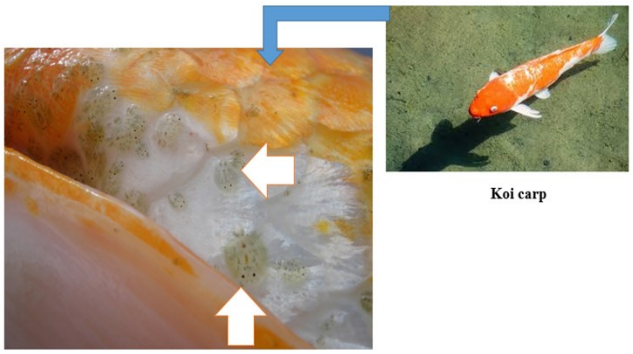

FIGURE 3 Prevalence of fish lice, *Argulus* on koi carp (modified from KHPC 2021).

5 | PREVALENCE OF ARGULUS IN NATIVE FISHES OF IRAN

So far, several studies have been conducted to identify parasitic species in the inland waters of Iran, the most important of which are Rasouli *et al.* (2011), Pazooki and Masoumian (2012) and Fathollahi (2014). In addition to confirming the presence of *A. foliaceus* in *Carassius auratus gibelio*, Pazooki and Masoumian (2012) also reported the prevalence of *Argulus* parasite in many other fish species such as common carp (*Cyprinus carpio*), *Chalcalburnus chalcoides*, *Lucioperca lucioperca*, *Esox lucius*, *Abramis brama*, *Alburnoides bipunctatus*, *Capoeta capoeta*, *Aspius aspius*, *Perca fluviatilis* and silver carp (*Hypophthalmichthys molitrix*). Fathollahi (2014) investigated parasitic infections of Zagros carp (*Aphanius vladykovi*) as an endemic species in Choghakhor wetland, Chaharmahal

and Bakhtiari province, western Iran. According to the findings, Zagros carp breeders were infected with *Argulus* parasite, which will have a negative impact on the survival of the population of this endemic species. In another study, Rasouli *et al.* (2011) examined parasitic infections of fish in Lake Marmisho, West Azerbaijan province, Iran. In addition to common bream (*A. brama*), Caucasian scraper (*C. capoeta*), common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*) and *Rutilus rutilus caspicus* were also infected with *A. foliaceus*.

As studies have shown, some species with parasitic infections are endemic whose populations have declined in recent years. There are several factors involved in reducing the population of these species, however, infection with parasitic agents such as *Argulus* can also have negative and significant effects on their population structure.

6 | SOLUTIONS AND SUGGESTIONS

This study offers the following suggestions to prevent the transmission of various parasitic species such as *Argulus* to native fish and natural ecosystems. Our first suggestion is accurate and strict monitoring to prevent the import of aquarium fish infected with parasitic diseases to Iran. It is recommended that monitoring measures be taken before transferring exported fish samples to farming centres. In this regard, it is necessary for the veterinary organisation to closely monitor the prevalence of parasitic diseases in fish, especially ornamental species. Another important solution is to closely monitor the health of breeding centres to prevent the growth and spread of microbial agents such as parasites. Certainly, the close supervision of the Iranian fisheries organisation on the proper implementation of breeding activities throughout the country will be very helpful. Also, as an essential suggestion, the participation of universities and research institutes in order to conduct studies on parasitic infections in native fish is recommended. This can be accelerated by funding universities and research institutes to expand studies. One of the important points to avoid ecological challenges in a society is to increase the level of public awareness. Due to this issue, it is necessary to inform the various segments of society in order to prevent the release of ornamental fish (such as goldfish) in natural ecosystems including rivers, wetlands, open waters and etc. In order to achieve this goal, it has been recommended to use the mass media such as radio, television and cyberspace in particular.

7 | CONCLUSIONS AND FUTURE PROSPECTS

The present study showed that aquarium fish such as goldfish and koi carp can act as hosts for transmitting parasitic species. Therefore, due to the high prevalence of various parasitic species including *Argulus* in these fish, it is essential to ensure the appropriate measures to control and prevent the entry of fish specimens with parasitic diseases. In fact, when trading aquarium fish, the necessary measures should be taken to prevent the introduction of transmissible pathogens that can cause serious diseases and economic losses. Hence, it is expected that the veterinary organisation and the fisheries organisation of Iran will have a comprehensive, continuous and sustainable participation in carrying out these preventive and control measures.

CONFLICT OF INTEREST

The author declares no conflict of interest.

AUTHORS' CONTRIBUTION

Both authors contributed equally to data collection and manuscript preparation.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on a reasonable request from the corresponding author.

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