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Biodiversity of Gill Fish parasites from the Algerian waters of the Gulf of Bejaia: new location and descriptions

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Abstract: Studying fish parasites is crucial for understanding their ecological impact, improving aquaculture practices, and reducing the risk of zoonotic transmission, thus protecting the environment, enhancing fish farming, and ensuring public health safety. The gills of 12 commercial fish species were examined for their parasites in the Gulf of Bejaia, Algeria. Several parasites were identified among these gill hosts. Nine crustaceans: Clavella adunca, Lernaea sp., Clavellisa emarginata, Naobranchia cygniformis, Hatschekia mulli, Lernanthropus kroyeri, Caligus elongatus, Gnathia marleyi, and Caligus sp., six monogeneans: Bivagina pagrosomi, Rajonchocotyle batis, Microcotyle erythrini, Squalonchocotyle squali, Paradiplozoon sp., and Tristoma integrum, and one Hirudinea, Trachelobdella lubrica were identified. In this study, we provide a new locality record from the Algerian Sea for R. batis, S. squali, and C. elongatus. Moreover, this paper presents new host and locality records for B. pagrosomi infecting Trachurus trachurus, Paradiplozoon sp. infecting Boops boops, and G. marleyi infecting Sparus aurata.
Keywords: fish, gills, parasite distribution, biodiversity, Bejaia area, Algerian waters.

1. Introduction

The respiratory organs of fish are the gills. In addition to their respiratory functions, they provide acid-base regulation, osmoregulation, and excretion of nitrogen compounds (Roberts and Smith 2011). Because of their close relationship with the environment, the gills are an important site as an entry point for pathogens. They are often the main target organ for pollutants and are sensitive to poor water quality and the presence of biological pathogens such as viruses, bacteria, fungi, and parasites (Roberts and Smith 2011; Novotny 2021). Therefore, it is often infected and damaged by causative agents, including ectoparasites, such as monogeneans, parasitic copepods, isopods, and leech parasites (Ramdani et al., 2020; Ramdani et al., 2021a; Ramdani 2023a; Ramdani and Ramdane 2024). The attachment of ectoparasites and their foraging activities can provoke gill lesions and cause alteration to the gill filaments, resulting in disruption of the respiratory process (Suliman et al., 2021; Vankara et al., 2022). Parasite scan can also lead to economic losses in commercial species of fish (Rameshkumar and Ravichandran, 2014; Paredes-Trujillo et al., 2021). For example, sea lice (*Lepeophtheirus salmonis*) are a major issue in salmon farming, causing annual losses exceeding $1 billion globally due to reduced growth, decreased market value, and high treatment costs (Costello, 2009). In freshwater aquaculture, tapeworms such as *Bothriocephalus acheilognathi* have caused significant losses, particularly in Asia, where infestations in carp farming result in reduced production worth millions of dollars annually (Scholz et al., 2012).

Knowledge of fish parasites is not only of particular interest for fish health but also for understanding ecological issues and detecting and treating parasites and diseases as part of marine aquaculture development (Li et al., 2022), and Algeria is no exception to this devastation (Meddour et al., 2011).

In the Gulf of Bejaia, Algeria, various fish species host a diverse array of parasitic organisms that can significantly affect their health and ecological fitness. *Sardinella aurita* (round sardinella), *Mullus barbatus* (red mullet), and many other species have been reported to harbor a variety of parasites, including trematodes, copepods, nematodes, and microsporidians (Ramdani et al., 2022b; Ramdani et al., 2023b). In *Xiphias gladius* (swordfish), copepod parasites have been associated with histopathological alterations in muscle tissue, resulting in compromised functionality and fitness (Ramdani et al., 2021b). Histological analysis of nematode infestations in fish musculature has revealed myodegeneration, characterized by the loss of striated texture in muscle fibers and associated skin damage (Ramdani et al., 2022a).

However, knowledge about marine fish gill parasites in Algerian waters remains relatively poor. This study examined the gills of several commercially valuable marine fish species for parasites to improve our knowledge of marine parasite biodiversity in Algerian waters.

2. Materials e Methods

The Gulf of Bejaia, located on the eastern coast of Algeria (36°45'21.13" N, 5°05'3.59" E), represents a significant ecological and economic zone along the northeastern Mediterranean. This region, characterized by a Mediterranean climate, supports diverse marine ecosystems and high levels of biological productivity. Economically, the gulf plays a vital role, with fishing and maritime trade through the Port of Bejaia contributing substantially to Algeria's local and national economies.

Between January and June 2022, a parasitological study was conducted on the gills of 12 commercially important fish species from the Gulf of Bejaia. The sampling strategy was influenced by the availability of fish, particularly for species that are less frequently captured in the region. A total of 59 fish specimens were collected from commercial landings, focusing on species that are both economically significant and commonly consumed by the local population. The gills were meticulously dissected to individually examine each gill arch and its associated filaments. Each gill filament was inspected for visible signs of parasitic infestations, such as attachment points, cysts, or external organisms, ensuring a thorough survey of the gill surfaces. Following dissection, the gills were immediately immersed in 25 mL glass jars containing distilled water and promptly transported in a cooler box to the Laboratory (LZA) at the University of Bejaia for further examination.

The gill arches and filaments were separately examined under the BS-3010A Binocular Stereo Microscope (objective 4x). Parasites were removed from the gills, washed, and cleaned in water. Copepod parasites were cleared in 85% lactic acid for 1 to 2 h and stored in 98% alcohol for further examination. Monogenean parasites were cleared with lactophenol (Carbonell et al., 1999) and stored in pure alcohol (98%) for further examination. The parasites were photographed using the LEICA DM300 microscope camera (manufactured by Leica Microsystems, headquartered in Wetzlar, Germany) under the light microscope and identified using identification keys (Williams and Lucy Bunkley-Williams, 1996).

Parasitological indexes (P (%): Prevalence; Im: Mean intensity; Am: Mean abundance) were calculated according to Bush et al. (1997) (Table 1).

Parasites groups	Parasites familly	Parasites genus	Parasites species	Host species	NEF	NIF	NP	P (%)	Im	Am
Monogeneans	Diplozoidae Palombi, 1949	*Paradiplozoon* Akhmerov, 1974	*Paradiplozoon* sp.	*Boops boops* (Linnaeus, 1758)	07	05	08	71.42%	1.6	1.14
	Capsalidae Baird, 1853	*Tristoma* Cuvier, 1817	*Tristoma integrum* Diesing, 1850	*Xiphias gladius* (Linnaeus, 1758)	04	04	07	100%	1.75	1.75
	Hexabothriidae Price, 1942	*Rajonchocotyle* Cerfontaine, 1899	*Rajonchocotyle batis* Cerfontaine, 1899	*Squalus acanthias* (Linnaeus, 1758)	02	02	14	100%	7	07
		Squalonchocotyle Cerfontaine, 1899	*Squalonchocotyle squali* MacCallum, 1931			02	17	100%	8.5	8.5
	Microcotylidae Taschenberg, 1879	*Microcotyle* Van Beneden & Hesse, 1863	*Microcotyle erythrini* van Beneden & Hesse (1863)	*Pagellus erythrinus* (Linnaeus, 1758)	07	04	03	57.14%	0.75	0.42
		Bivagina Yamaguti, 1963	*Bivagina Pagrosomi* Murray (1931)	*Trachurus trachurus* (Linnaeus, 1758)	05	01	06	20%	06	1.2
Crustaceans	Lernaeopodidae Milne Edwards, 1840	*Naobranchia* Hesse, 1863	*Naobranchia cygniformis* Hesse, 1863			03	09	60%	03	1.8
		Clavella Oken, 1815	*Clavella adunca* (Strøm, 1762)	*Sardinella aurita* (Valencienne, 1847)	05	05	05	100%	01	01
		Clavellisa Wilson C.B., 1915	*Clavellisa emarginata* (Krøyer, 187)			03	11	60%	3.66	2.2
	Lernanthropidae Kabata, 1979	*Lernanthropus* de Blainville, 1822	*Lernanthropus kroyeri* Beneden, 1851	*Seriola dumerili* (Risso, 1810)	02	02	13	100%	6.5	6.5
	Caligidae Burmeister, 1835	*Caligus* Müller O.F., 1785	*Caligus elongatus* Nordmann, 1832			02	03	40%	1.5	1.5
			Caligus sp.			02	05	100%	2.5	2.5
	Hatschekiidae Kabata, 1979	*Hatschekia* Poche, 1902	*Hatschekia mulli* (van Beneden, 1851)	*Mullus barbatus* (Linnaeus, 1758)	07	01	01	14.28%	0.14	0.14
	Gnathiidae Leach, 1814	*Gnathia* Leach, 1814	*Gnathia marleyi* Farquharson, Smit & Sikkel, 2012	*Sparus aurata* (Linnaeus, 1758)	04	04	06	100%	1.5	1.5
	Lernaeidae Cobbold, 1879	*Lernaea* Linnaeus, 1758	*Lernaea* sp.			01	03	25%	03	03
Hirudinea	Piscicolidae Johnston, 1865	*Trachelobdella* Diesing, 1850	*Trachelobdella lubrica* (Grube, 1840)			01	01	25%	01	01
An unidentified parasites forms				*Engraulis encrasicolus* (Linnaeus, 1758)	05	01	01	20%	0.2	0.2
				Sardina pilchardus (Walbaum, 1792)	07	02	04	28.57%	02	0.57
				Merlangius merlangus (Linnaeus, 1758)	04	01	05	25%	05	1.25
				Xiphias gladius (Linnaeus, 1758)	04	01	04	25%	04	04

Table 1 – Infection rates of parasite species recorded per host fish. NEF: Number of the examined fishes; NIF: Number of the infested fishes; NP: Number of parasites; P (%): Prevalence; Im: Mean intensity; Am: Mean abundance.

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3. Results

Parasites from groups of crustaceans, monogeneans, and Hirudinea were identified among these gill hosts. The morpho-anatomical analysis identified nine crustacean parasite species: *Clavella adunca* (Strøm, 1762), *Lernaea* sp., *Clavellisa emarginata* (Krøyer, 1847), *Naobranchia cygniformis* (Hesse, 1863), *Hatschekia mulli* (Van Beneden, 1851), *Lernanthropus kroyeri* (Van Beneden, 1851), *Caligus elongatus* (Nordmann, 1832), *Gnathia marleyi* (Farquharson, Smit & Sikkel, 2012), and *Caligus* sp. (Fig. 1), (Table 1). Six monogenean parasite species were identified: *Bivagina pagrosomi* (Murray, 1931), *Rajonchocotyle batis* (Cerfontaine, 1899), *Microcotyle erythrini* (Van Beneden & Hesse, 1863), *Squalonchocotyle squali* (MacCallum, 1931), *Paradiplozoon* sp., and *Tristoma integrum* (Diesing, 1850) (Fig. 2), (Table 1) along with One leech, *Trachelobdella lubrica* (Grube, 1840) (Fig. 3), (Table 1). Several unidentified parasite forms were also collected (Fig. 4) (Table 1).

The examination of *B. boops* allowed us to collect a monogenean *Paradiplozoon* sp. (Fig. 2E), and on *X. gladius*, the parasite *T. integrum* (Fig. 2F). On *S. acanthias*, we harvested parasites species *R. batis* (Fig. 2B) and *S. squali* (Fig. 2D). *M. erythrini* (Fig. 2C) collected on *P. erythrinus*. On fish host *T. trachurus*, we collected *B. Pagrosomi* (Fig. 2A) and *N. cygniformis* (Fig. 1D). Parasites *C. adunca* (Fig. 1A) *and C. emarginata* were collected on *S. aurita* (Fig. 1C) and. The species *L. kroyeri* (Fig. 1F), *C. elongatus* (Fig. 1G), and *Caligus* sp. (Fig. 1I) were found on S. *dumerili*, *H. mulli* (Fig. 1E) were found on the gills host *M. barbatus*, whereas *G. marleyi* (Fig. 1H), *Lernaea* sp. (Fig. 1B) and *T. lubrica* (Fig. 3) were collected on *S. aurata*. unidentified parasite forms, were also collected from host fishes *E. encrasicolus* (Fig. 4F), from *S. pilchardus* (Fig. 4E), *M. merlangus* (Fig. 4A, B, C) and from *Xiphias gladius* (Fig. 4D).

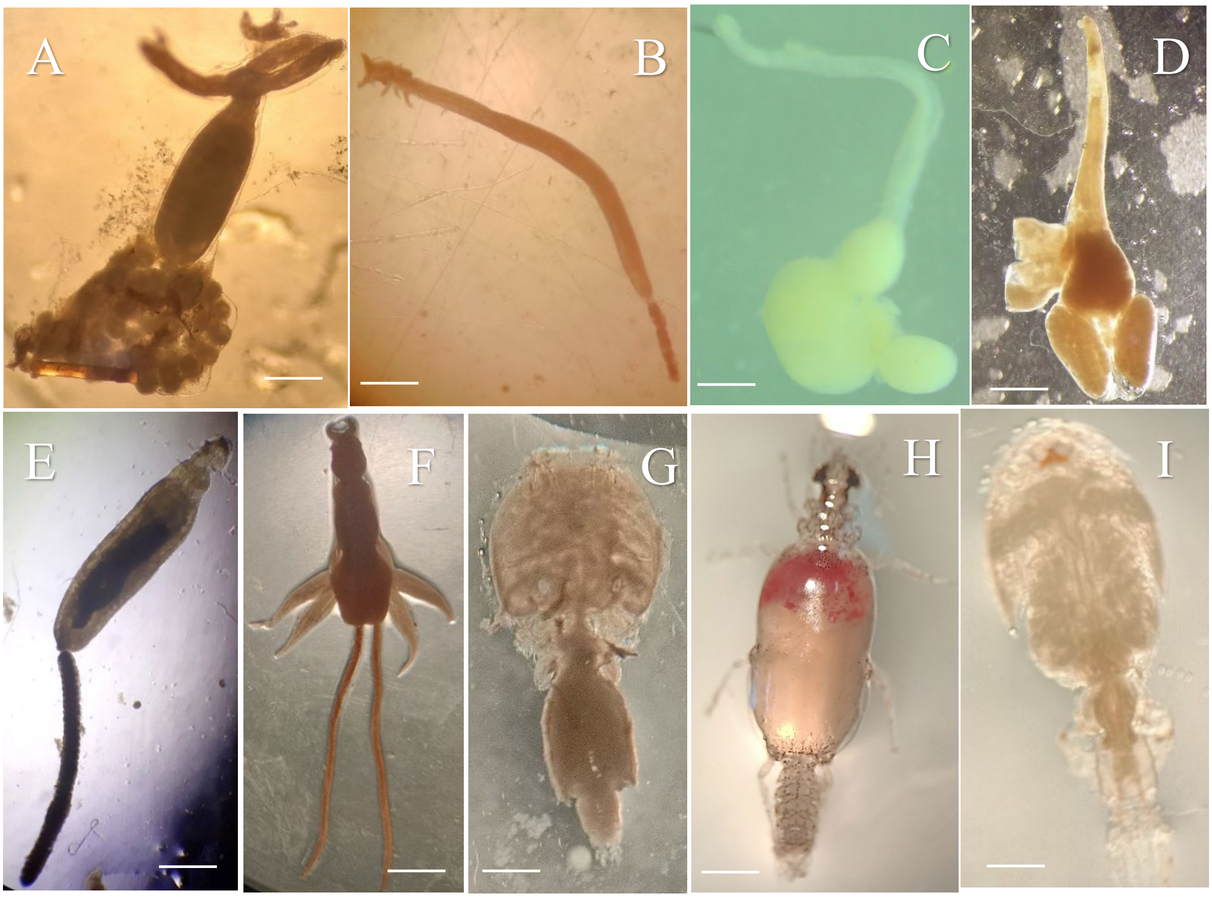

Figure 1 – photo of collected crustacean parasites. A: Clavella adunca; B: Lernaea sp.; C: Clavellisa emarginata; D: Naobranchia cygniformis; E: Hatschekia mulli; F: Lernanthropus kroyeri; G: Caligus elongatus; H: Gnathia marleyi; I: Caligus sp. Scale bar: A, B, C, D, E; F; G; H, I; (Gx10); 0.5 mm.

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Figure 2 – Photo of collected monogenean parasites. A: *Bivagina Pagrosomi*; B: *Rajonchocotyle batis*; C: *Microcotyle erythrini*; D: *Squalonchocotyle squali*; E: *Paradiplozoon* sp.; F: *Tristoma integrum*. Scale bar: A, B, C, D, E, F, G : (Gx10); 0,5 mm.

Figure 3 – Photo of Hirudinea, *Trachelobdella lubrica*. Scale bar: (Gx10), 0.5 mm.

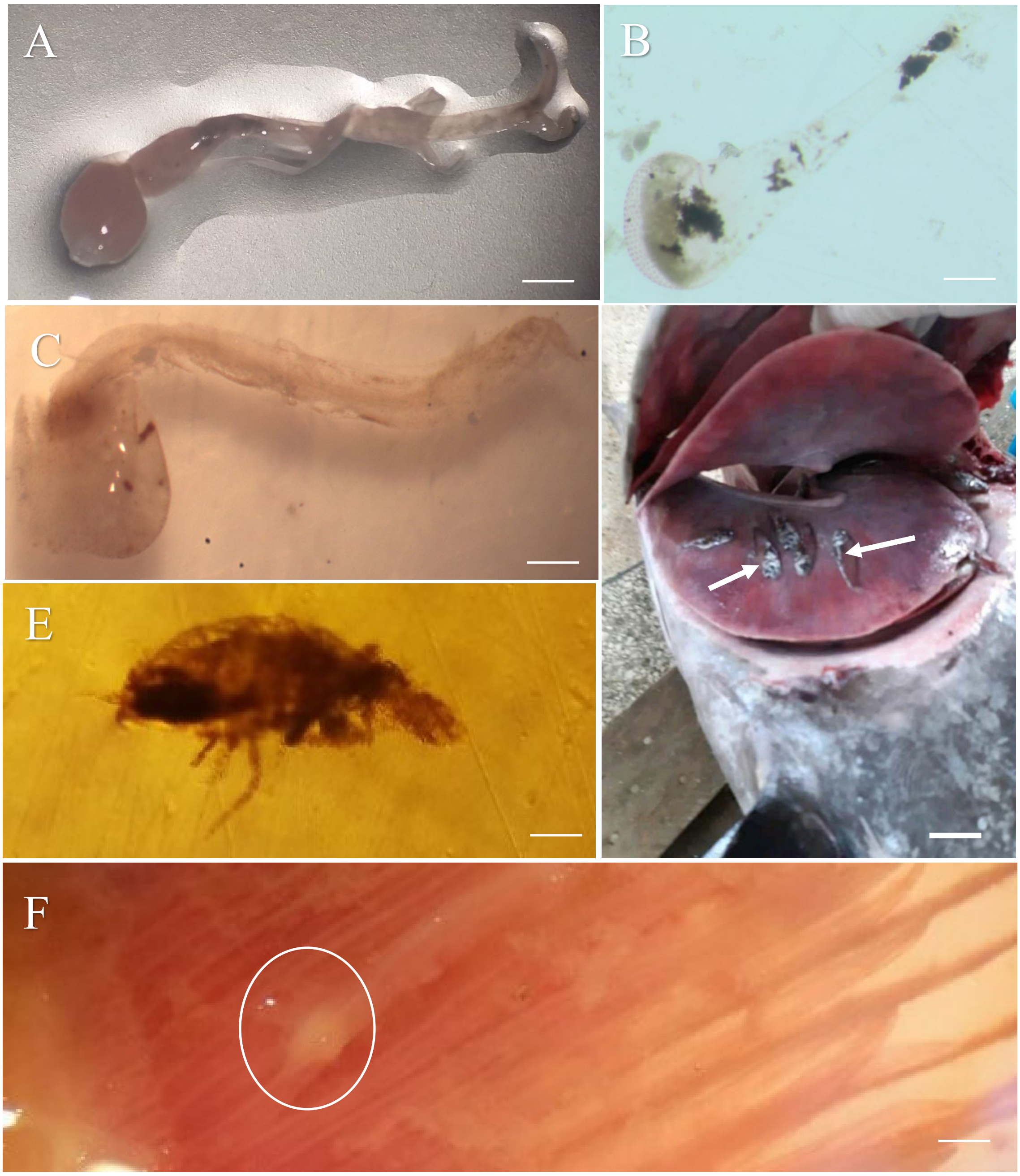

Figure 4 – Photo of unidentified parasite forms. A, B, C: parasite forms collected from *Merlangius merlangus*; D: parasite forms collected from *Xiphias gladius* (see white arrows); E: parasite form collected from *Sardina pilchardus*; F: parasite form collected from Engraulis encrasicolus (see white circle). Scale bar: A, B, C, E, F: (Gx10), 0.5 mm, D: 1mm.

Among all the fish, four host species were infested by monogenean parasites, and three species were infested by crustaceans. Notably, two of the host species were found to be infested by two different groups of parasites: *T. trachurus* was infested by both monogeneans and crustaceans, while *S. aurata* was infested by crustaceans and Hirudinea.

The parasitological survey revealed significant variability in the prevalence, intensity, and abundance of parasites across different host species from the Gulf of Bejaia. The prevalence (P%) of infection varied widely among host species, with certain associations showing extremely high rates. For instance, *Tristoma integrum* in *Xiphias gladius* and *Clavella adunca* in *Sardinella aurita* exhibited a prevalence of 100%. Conversely, other parasites, such as unidentified forms in *Engraulis encrasicolus*, showed much lower prevalence rates (20%). Mean intensity (Im) and mean abundance (Am) also displayed significant interspecies variability. Notably, *Squalonchocotyle squali* in *Squalus acanthias* demonstrated exceptionally high values (Im = Am = 8.5), indicating heavy infestations in the affected hosts. (Table 1).

Clavellisa emarginata presented a prevalence of 60% in *Sardinella aurita*, demonstrating its widespread presence in this host species. Monogeneans, while limited in species richness, showed variable prevalence, as evidenced by *Microcotyle erythrini* in *Pagellus erythrinus* (P = 57.14%). (Table 1).

4. Discussion

Our work focuses on the study of gill parasites collected from several species of fish caught in the Gulf of Bejaia. A parasitological study was conducted on 12 fish species, 59 fish. The aim WAS to determine the taxa of parasites hosted by these fish species to understand the host-parasite relationship. Sixteen species of parasites were identified, belonging to three groups of ectoparasites: crustaceans, monogeneans, and Hirudinea.

The morphology, arrangement, and number of sclerified parts of the haptor, as well as the anatomy of different systems, allow for the classification of the collected monogenean specimens into four distinct families: Diplozoidae Palombi, 1949 (genus: *Paradiplozoon Akhmerov*, 1974), Capsalidae Baird, 1853 (genus: *Tristoma* Cuvier, 1817), Hexabothriidae Price, 1942, (genus: *Rajonchocotyle* Cerfontaine, 1899 and genus: *Squalonchocotyle* Cerfontaine, 1899), Microcotylidae Taschenberg, 1879 (genus: *Microcotyle* Van Beneden & Hesse, 1863 and genus: *Bivagina* Yamaguti, 1963).

The species *Tristoma integrum* appears to be closely associated with the host species *Xiphias gladius*. Its presence has already been reported in the same host species by Ramdani et al. (2021) in the Gulf of Bejaia and by Euzet and Quignard (1961) along the French coasts. As for the species *Rajonchocotyle batis* and *Squalonchocotyle squali*, they seem to be closely linked to the host species *Squalus acanthias*. In this study, we provide a new locality record from the Algerian Sea. Their presence has already been noted by Maillard (1970) in the south of France in the same host species. *Microcotyle erythrini* is mostly characterized by its specific host, *Pagellus erythrinus*, as authors provided from Mediterranean Sea, Ulmer and James (1981) from Italy, Jovelin and Justine (2001) from France, Kaouachi et al. (2010) from Algeria and Víllora-Montero et al. (2020) from Spain. *Bivagina Pagrosomi* infecting *Trachurus trachurus* presents the first report of this species with a new host and locality record in the Algerian waters. Previously, this monogenean species was reported to infect *Sparus aurata* in Saudi Arabia by Dajem et al. (2019). Genus: *Paradiplozoon* has previously been documented to infect cyprinoid fishes (Al-Nasiri, 2010; Benovics et al., 2021). In this study, we report the first record of a *Paradiplozoon* sp. with the new host record *Boops boops*.

The observation of the general shape of the body, segmentation, and appendages of crustaceans reveals the presence of six families: Lernaeopodidae Milne Edwards, 1840 (genus: Naobranchia Hesse, 1863, genus: Clavella Oken, 1815 and genus: Clavellisa Wilson C.B., 1915), Lernanthropidae Kabata, 1979 (genus: *Lernanthropus* de Blainville, 1822), Caligidae Burmeister, 1835 (genus: *Caligus* Müller O.F., 1785), Hatschekiidae Kabata, 1979 (genus: *Hatschekia* Poche, 1902), Gnathiidae Leach, 1814 (genus: *Gnathia* Leach, 1814) and Lernaeidae Cobbold, 1879 (genus: *Lernaea* Linnaeus, 1758).

A wide variety of crustacean parasites have been documented along Algeria's coastlines, especially within the Gulf of Bejaia. Notably, *Naobranchia cygniformis* was found on species such as *Sparus aurata* and *Boops boops*, as detailed by Hafir Mansouri et al. (2017) and Boualleg et al. (2011). Additionally, *Clavellisa emarginata* infecting *Alosa fallax* algeriensis was recorded by Hafir Mansouri et al. (2017) and Ramdani et al. (2020), while *Lernanthropus kroyeri* was identified on the gills of *Dicentrarchus labrax* by Boualleg et al. (2011). The presence of *Hatschekia mulli* in *Mullus barbatus* was also highlighted by Boualleg et al. (2011). Furthermore, the *Lernaea* genus was notably reported from Algerian waters with specific species noted by Berrouk et al. 2018. Species from the genus *Caligus*, particularly noted by Ramdane and Trille 2010, were identified in *Lithognathus mormyrus* and *Mullus barbatus*, marking the first identification of *Caligus elongatus* on the Algerian coastline. Moreover, this paper presents the first detection and new host of *Gnathia marleyi* infecting *Sparus aurata* in Algeria, a parasite originally described in the Caribbean by Farquharson et al. (2012).

Moreover, the collection of unidentified parasite forms from several host fishes indicates the potential for discovering new parasite species, highlighting the importance of continuous monitoring and research in marine parasitology. This not only aids in the documentation of biodiversity but also in understanding the ecological roles these parasites play in marine ecosystems.

Several authors have previously reported the infection of gills by the same groups of parasites identified. Our results did not show an apparent pathogenic effect linked to the presence of these parasites (Monogeneans and Crustaceans). Many authors have pointed out the existence of pathologies following gill infections by parasites. For example, we mention the infection of the gills of *Lates albertianus* by the Monogenean *Diplectanum lacustris*, which stimulates extensive hyperplasia of the branchial epithelium around the parasite's attachment point. These cellular changes affect the branchial respiratory function and directly cause the death of the fish (Oliver 1977; Paperna 1991).

The attachment of specimens of *Ergasilus megacheir* (Sars G.O., 1909) (Copepods: Ergasilidae) to the branchial filaments of Cichlids (Fryer 1968) causes erosion. Such erosion processes often lead to significant hyperplasia of the epithelium, which, when the infection is prolonged, can extend over large areas of the gills, causing the fusion and embedding of the lamellae, with the consequence of a reduction in the respiratory function of the gills (Kabata 1970; Paperna and Zwerner 1981). The economic losses due to the infection result not only from the direct damages caused to fish but also from the disfigurement that makes fish raised for food and ornamental fish unfit for sale.

Crustaceans were the most frequently recorded parasite group. Similarly, *Clavellisa emarginata*, reported by Ramdani et al. (2020) in *Sardinella aurita*, also appeared in this study with a significant prevalence of 60%, reinforcing its ecological importance among Algerian fish hosts. The indices of prevalence (P%), mean intensity (Im) and mean abundance (Am) provide a quantitative understanding of host-parasite interactions. For example, *Clavella adunca* in *Sardinella aurita* exhibited a prevalence of 100%, emphasizing a highly specialized host-parasite relationship. Conversely, *Hatschekia mulli* in *Mullus barbatus* showed a much lower prevalence of 14.28%, indicating less frequent interactions or differences in ecological niches.

This study adds to the regional biodiversity with observations of *Gnathia marleyi* in *Sparus aurata* and *Lernanthropus kroyeri* in *Seriola dumerili*. These findings complement previous reports of crustacean parasites infecting various Algerian fish species (Ramdani and Ramdane, 2024). The high prevalence of crustaceans and other parasites in commercially important species, such as *Sardinella aurita* and *Mullus barbatus*, underscores the potential economic and ecological impacts of parasitism. Infestations may affect fish quality and yield, necessitating improved management strategies in fisheries and aquaculture.

5. Conclusion

This study enriched our knowledge of the parasitic fauna in the Gulf of Bejaia, highlighting the significance of such research in understanding ecological relationships, biodiversity, and the potential implications for marine resource management and conservation. Further research focusing on the life cycles, impact on host fitness, and ecological roles of these parasites could provide deeper insights into the complex web of interactions within marine ecosystems.

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