**Helminth parasite and Microbiota in Gut Marine Fish**-review

**Abstract**

A fish's gut contains many types of bacteria that are important for digestion, food absorption, and immunity. Marine parasites, such as trematodes, cestodes, and nematodes, affect the gut microbiota and cause histopathological alterations in marine fish. However, the gut microbiota and helminth parasites share a habitat. There are several mechanisms of interactions between microbiota and parasites in the gut, such as physical changes to the gastrointestinal microbial environment and innate immunity. So, managing fisheries and improving fish health depend on understanding these consequences. Further research is needed to better understand the underlying mechanisms as well as their larger implications.

**Keywords:** Marine Fish, marine, helminth parasites, histopathology, gut microbiota

**Introduction**

Because of the effects that parasitic infections have on both the host's health and the ecology as a whole, marine fish infestations are a serious concern. the marine Fish is often afflicted with parasite illnesses that can change its gut flora and histology. The intricate community of bacteria known as the gut microbiota is essential to the host's health because it supports immune system, nutrition absorption, and digestion [1]. This delicate equilibrium is upset by parasitic infestations, which result in dysbiosis and increase the host's vulnerability to illness [2].

Research has demonstrated that parasite infections can drastically change the variety and makeup of fish gut microbiota. For example, protozoa and helminths can cause additional disruptions to the gut environment by competing with the host for nutrition, secreting toxins, and triggering inflammatory responses [3]. Histopathological abnormalities in the gut, including epithelial injury, mucosal inflammation, and fibrosis, may result from these modifications [4]. For the purpose of managing and treating parasite diseases in marine fish, it is vital to comprehend these relationships.

The extreme salinity and warmth of the Red Sea may have an impact on the frequency and severity of parasite infestations in emperor fish [5]. Researching these consequences within the framework of the marine ecosystem, therefore, offers important new perspectives on the wider effects of parasitic diseases on marine biodiversity and fisheries resources.

The purpose of this research is to examine how parasitic infections affect the composition of the gut microbiota and histopathological alterations in marine Fish. In order to improve our comprehension of host-parasite-microbiota interactions in marine habitats, this research examines changes in gut microbial populations and tissue pathology linked to parasitic infections. The results will aid in the creation of sensible management plans that will preserve the sustainability and well-being of fish populations within the marine Sea environment.

**Nematode parasitic infestations in marine fish**

Because of its effects on fish health and the larger marine ecology, nematode parasitism in marine fish is a serious concern. Nematode infections are a prevalent problem for the marine Fish , which are regularly seen in the marine Sea .These infections may cause serious gastrointestinal problems that impair the fish's ability to develop, survive, and maintain general health. This article focuses on the life cycles, pathogenic effects, and types of nematodes that affect marine fish[6–7].

*Anisakis* species, also referred to as cod worms or herring worms, are important because they have the ability to transmit a zoonotic disease that can result in anisakiasis in humans who eat raw or undercooked fish. Another significant nematode that affects marine fish *Pseudoterranova* sp., and *Contracaecum* sp., and the most common nematode found in marine fish is *Anisakis simplex,* which is known to induce digestive problems in fish [8].

Fish that are infected with nematodes experience severe intestinal inflammation and ulceration. They impede the absorption of nutrients, resulting in stunted growth and malnourishment. Mortality rates may rise with severe infestations Because of decreased fish quality and greater mortality, infestations can also result in financial losses in aquaculture and fisheries [7].

**Cestode parasitic infestations in marine fish**

Since cestode parasitism affects both fish health and the larger marine ecosystem, it is of great concern. One species of fish that is commonly affected by cestode infections is the marine Fish ,which can have severe gastrointestinal problems that impair the fish's ability to grow, survive, and maintain overall health [9–10] . Because they have the ability to spread zoonotic disease when raw or undercooked fish is consumed. Often present in fish intestines, cestodes *Pseudotobothrium dipsacum,* *callitetrarhynchus gracilis* , *Floriceps minacathus* , *Pseudogrillotia* sp., and *Nybelinia bisulcate* [11-12]

Cestodes may induce noteworthy ulceration and inflammation in the intestinal tract of infected fish, leading to malnutrition and reduced growth rates [13-14]. Massive infestations may also elevate the number of deaths resulting in economic losses in aquaculture and fisheries [15].

**Trematode parasitic infestations in marine fish**

Trematode infection in marine fish is a major problem because of its effects on fish health and the overall marine ecology. Trematode infections usually affect the marine fish.These parasitic infections may cause serious gastrointestinal problems that impair the fish's ability to develop, survive, and maintain general health [16-17–18].

*Haplosplanchnus* spp. are frequently detected in herbivorous fish's digestive tracts, where they can cause significant inflammation and nutrition absorption difficulties [19].

The gut of Fish that are infected with trematodes experience severe inflammation and ulceration in the gastrointestinal tract [20]. They impair the absorption of nutrients, resulting in stunted growth and malnourishment. Mortality rates may rise with severe infestations . Because of decreased fish quality and increased mortality, infestations can also result in financial losses in aquaculture and fisheries [16-17].

**Histopathological Effects of parasitic infestations on gut of marine fish**

The marine parasite infestations represent a serious risk to the general health of marine fish .Nematodes, cestodes, and trematodes are especially well-known among the many parasites for their negative impact on the gut histology of these fish. These parasites have the potential to severely inflame the gut, ulcerate it, and induce fibrosis. This can hinder the absorption of nutrients, result in malnutrition, and raise death rates. [15].

To preserve the health of Fish and guarantee the sustainability of their populations, it is essential to understand the precise histopathological alterations produced by these worms . The histopathological consequences of each of these parasite types on the intestine of fish will be covered in this section in detail. [21].

**Histopathological Effects of Nematodes on the Gut of marine Fish**

In the Marine Sea, nematode infestations pose a serious threat to the wellbeing of fish . These parasites can seriously alter the gut's histopathology, which can result in a number of health problems that impair the fish's ability to develop, survive, and generally feel good [22].

Considerable histological alterations are brought about by these worms, including the gut lining becoming severely inflamed and ulcerated. A robust immunological response is triggered by the presence of nematode larvae in the gut wall, which results in granuloma development and fibrosis [23]. The typical architecture of the gut tissue may be disturbed by the inflammation brought on by worm infections. This involves the intestinal wall becoming thicker as a result of inflammatory cells like lymphocytes, macrophages, and eosinophils infiltrating the body. As a result of the immune cell clusters known as granulomas that are created in reaction to the nematode larvae, there may be a loss of functional gut tissue due to fibrosis and localized tissue damage [24].

Another frequent histological consequence of nematode infections is ulceration of the intestinal walls. Ulcers can develop as a result of the nematodes' feeding and movement-induced mechanical damage to the mucosal layer. Fish with infections may experience malnourishment and slowed growth rates as a result of these ulcers, which can further impair the gut's capacity to absorb nutrients [25].

In severe circumstances, nematode infections cause considerable tissue damage and inflammation, which can lead to subsequent bacterial infections. The decreased gut integrity allows opportunistic bacteria to enter, aggravating the fish's health issues. This can dramatically increase death rates in the affected populations [26].

**Histopathological Effects of Cestodes on the Gut of Marine Fish .**

In the Marine Sea, cestode infestations pose a serious threat to the health of fish. The growth, survival, and general well-being of fish can be adversely affected by these parasites' significant histological alterations in the gut, which can result in a number of health problems [27–28].

Cestodes have an organ called the scolex that serves as a holdfast and is designed to adhere to the intestinal mucosa. This adhesion may result in ulceration and mucosal layer erosion, among other localized tissue injury. Granulomas, which are immune cell clusters produced in reaction to the parasite, might develop as a result of the mechanical irritation brought on by the scolex [29].

Cysts in the gut wall can also result from cestode infections. The natural in of the gut tissue can be seriously disrupted by these cysts, which are habitat to the parasites' larval stages. These cysts may cause fibrosis, a condition in which scar tissue replaces normal tissue, which worsens the body's ability to absorb nutrients [30].

Furthermore, the existence of cestodes in fish gut may disturb normal peristalsis, resulting in stasis and subsequent infections with bacteria. The decreased gut integrity allows opportunistic bacteria to enter, aggravating the issues with health of infested fish. This can dramatically raise death rates in impacted populations of fish [29].

**Histopathological Effects of Trematode on the Gut of Marine Fish .**

trematodes may result in characteristic histopathological abnormalities in affected fish. One of the most affected organs is the intestine [31]. The main pathological findings in the intestine of marine fish infested with trematode were desquamation of intestinal villi with hypertrophy the muscular layer [31]. Trematodes physically disturb and harm the mucosal layer of the intestinal lining by attaching themselves to it by suckers and by feeding mainly on epithelial cells. This results in destruction of the mucosal epithelium covering the intestinal folds, thus causing local inflammation and cell necrosis [32]. Adult digenean trematodes and encysted metacercariae which were detected inside the intestinal lumen or embedded in the muscular layer cause hypertrophy. Other sections showed the adult digenean trematodes embedded in between intestinal villi resulting in desquamation of intestinal villi or detected in the lumen. The appearance of rodlet cells and other inflammatory cells in the submucosa were noticed [32].The numerous rodlet cells which have large granules and rod-like core in the infected intestines as a defense mechanism. Rodlet cells seemed to be recruited when helminths affected the epithelial tissues [31].

**Gut Microbiota in Marine Fish: Diversity and Functional Roles**

The gut microbiota of Mariner fish, like that of other fish species, is critical to the health and well-being of the host. The phrase "microbiota" refers to the gastrointestinal tract's community of microorganisms, which includes bacteria, archaea, viruses, and fungi. These microbes are engaged in a variety of physiological activities, including digestion, food absorption, and immune system regulation. Bacteria belonging to the groups Proteobacteria, Firmicutes, and Bacteroidetes make up the majority of the gut microbiota of emperor fish. Most of the time, Proteobacteria are the most prevalent, followed by Firmicutes and Bacteroidetes. A host's genetic composition, environment, and food are among the variables that affect these bacterial populations [33–35].

The marine fish's gut microbiota plays a major role in its digestive system by facilitating the digestion of complex proteins and carbs and improving the absorption of nutrients. In addition, microbiota generates additional metabolites, such as short-chain fatty acids (SCFAs), that support gut health and provide the host with energy [36,37].

**Effect of Gut Fish Microbiota on Marine Parasites**

Marine parasites are susceptible to several effects of the intestinal microbiota. Initially, metabolites that directly impact the viability of parasites can be produced by microbiota. For example, some types of bacteria can create antimicrobial chemicals, such as short-chain fatty acids (SCFAs), that can stop parasites like nematodes, cestodes, and trematodes from growing and developing [38].

Furthermore, the host's immune response can be modulated by microbiota, improving the recognition and removal of parasite infestation. For instance, a healthy gut microbiota can promote the development of immunological components and mucosal antibodies that specifically target parasites, hindering their ability to colonize and spread throughout the host [39].

Moreover, by competing with parasites for resources and available space, the gut microbiota can make the environment less favorable for parasite survival. Due to resource limitations brought forth by this competitive exclusion, parasite viability and reproductive success could be impaired [40]. It has been demonstrated that certain bacterial taxa in the microbiota of the gut can occasionally create bioactive compounds that hinder parasite development and signaling, making it harder for the parasites to spread among the host [41].

**Effect of Marine Parasites on Gut Microbiota**

The gut microbiome can be significantly impacted by marine parasites as well. The microbial community in the gut can undergo compositional and diverse alterations as a result of parasitic infections. Nematodes, cestodes, and trematodes, for example, can upset the delicate balance of good bacteria, resulting in dysbiosis, a condition marked by an imbalance in the community of microbes which may compromise the health of the gut [42]. This dysbiosis can result in the overgrowth of opportunistic pathogens and a reduction in beneficial microbial populations, further exacerbating the negative impact on the host’s health [43].

In addition to causing inflammation and harm to the intestinal lining, parasites can also create an environment that is more suitable to the growth of some bacteria species than others. Microbial colonization and growth may be impacted by this inflammation, which can change the chemical and environmental conditions of the gut [44].

Moreover, parasites could produce chemicals that alter the host's immune response and alter the composition of the gut microbiota. As an example, certain parasites create immunomodulatory proteins that weaken the host's immune system and promote greater colonization of the parasites as well as specific species of bacteria [45].

**Interaction Between Gut Microbiota and Marine Parasites**

Marine parasites and gut microbiota have a complicated, reciprocal relationship. The composition and function of the gut microbiota can be altered by parasites, and the gut microbiota can affect the establishment, survival, and expulsion of parasites. The results of the disease and the host's health may be significantly impacted by this dynamic interaction [43,46].For example, by enhancing immune function and competitive exclusion of parasites, a healthy and diverse gut microbiota can improve the host's resistance to parasitic diseases . On the other hand, dysbiosis brought on by parasite infections may weaken the host's immune system and make it more vulnerable to subsequent infections [46]. The coexistence of marine parasites and gut microbiota might result in a feedback loop where modifications to one element affect the other and have a cascading impact on the host's health.

**Combined Effect of Gut Microbiota and Marine Parasites on Fish Health**

The coexistence of marine parasites and gut microbiota in the fish gut can affect the host in both positive and negative ways. One way, by improving immune function and competitively excluding parasites, a well-balanced gut microbiota can lessen the harmful effects of parasitic infections. On the other side, infection with parasites can upset the balance of the gut microbiota, which can result in dysbiosis and poor gut health [44].

The host's metabolic processes may also be impacted by the interaction between marine parasites and the gut flora. As an instance, some species of bacteria have the ability to create metabolites that improve the host's energy metabolism and nutritional absorption, which can assist offset the nutrient depletion brought on by parasite infections .Furthermore, the microbiota of the gut can influence how the host responds to infections by lowering inflammation and encouraging tissue repair, that may decrease the harm that parasites can do. [45]

However, there may be detrimental effects on the host's health if the equilibrium between parasites and gut flora is disturbed. Chronic inflammation and dysbiosis can damage the integrity of the gut, making people more prone to infections and lowering their level of fitness and general health .Thus, preserving a balanced and healthy gut microbiota is essential to alleviating the negative effects of marine parasites and enhancing fish health in general [43].

**Conclusion**

The complex and diverse relationships between host, microbiota, and parasites are highlighted by the assessment of the impact of marine parasitic infestations on gut microbiota and histopathology in marine Fish from the Red Sea . The gut microbiota, which is mainly made up of Firmicutes, Bacteroidetes, and Proteobacteria, is essential to the health and homeostasis of marine Fish. This delicate equilibrium, however, can be disturbed by parasitic infestations such as nematodes, cestodes, and trematodes. This can result in notable changes to the gut microbial ecology and histological changes in the gastrointestinal tissue.

Dysbiosis, which is characterized by a rise in opportunistic pathogens and a decrease in beneficial microbial communities, is frequently the outcome of parasitic infections. The host's immune system may be weakened by this microbial imbalance, leaving the fish more vulnerable to diseases and infections in the future. According to histopathological analyses, parasite populations lead to tissue damage, inflammation, and morphological alterations in the gut that can affect the absorption of nutrients and the general health of the gut.Complex interactions occur between gut microbiota and parasites in both directions. Parasites can alter the gut environment to support their survival, frequently at the expense of the host's health, but a healthy microbiota can strengthen the host's resistance to infections caused by parasites through competitive exclusion and immunological regulation. The significance of preserving a well-balanced gut microbiota in reducing the negative consequences of parasitic infections is highlighted by this dynamic interaction.

Research on marine parasitic infestations' effects on marine Fish gut microbiota is crucial for effective management and conservation strategies, involving potential interventions like probiotics and dietary modifications.

**Recommendations**

It is recommended to regularly evaluate fish populations' gut microbiota and parasitic burden in order to mitigate the negative impacts of marine parasite infestations on gut microbiota and histopathology in marine Fish

Investigating the usage of probiotics and prebiotics may aid in the restoration and maintenance of an optimal gut microbiome. It is also critical to investigate dietary changes that boost the body's defenses and resistance to infections by parasites. Enhancing research into the processes of host-microbiota-parasite interactions will help to create tailored treatment options.

**Conflict of Interest**

The authors declare no conflict of interest

**Ethical Approval**

This review article does not include any direct experimentation or data collection with animals or humans. Therefore, ethical approval was not necessary. The information offered is based on a thorough review of the existing literature and studies. All sources have been properly credited to guarantee academic honesty and ethical standards in research and publication.

**References**

1. Naveed A, Abdullah S. Impact of parasitic infection on human gut ecology and immune regulations. Transl Med Commun 2021;6(1).

2. Mladineo, I., Hrabar, J., Vrbatović, A., Duvnjak, S., Gomerčić, T., & Đuras, M. (2019). Microbiota and gut ultrastructure of Anisakis pegreffii isolated from stranded cetaceans in the Adriatic Sea. *Parasites & vectors*, *12*, 1-15.‏

3. Grondin JA, Jamal A, Mowna S, Seto T, Khan WI. Interaction between Intestinal Parasites and the Gut Microbiota: Implications for the Intestinal Immune Response and Host Defence. *Pathogens*. 2024; 13(8):608. https://doi.org/10.3390/pathogens13080608

4. Ulusan Bagci O, Caner A. The interaction of gut microbiota with parasitic protozoa. J Parasit Dis. 2022 Mar;46(1):8-11. doi: 10.1007/s12639-021-01443-5.

5. Gaulke CA, Martins ML, Watral VG, Humphreys IR, Spagnoli ST, Kent ML, et al. A longitudinal assessment of host-microbe-parasite interactions resolves the zebrafish gut microbiome’s link to Pseudocapillaria tomentosa infection and pathology. Microbiome 2019;7(1).

6. Sayyaf Dezfuli B, Scholz T. Fish parasites (special issue). Parasitology 2022;149(14):1811–4.

7. Aguilar-Aguilar R, Ruiz-Campos G, Martorelli S, Montes MM, Martínez-Aquino A. A New Species of Ascarophis (Nematoda: Cystidicolidae) Parasitizing Clinocottus analis (Pisces: Cottidae) from Baja California, Mexico. Journal of Parasitology 2019;105(4):524–32.

8. Klimpel S, Palm HW. Anisakid Nematode Infections in Marine Fish: An Update. Int J Parasitol 2011;41(14):1423–37.

9. Ogawa, K. (2015). Diseases of cultured marine fishes caused by Platyhelminthes (Monogenea, Digenea, Cestoda). *Parasitology*, *142*(1), 178-195.‏

10. Scholz, T., Kuchta, R., & Oros, M. (2021). Tapeworms as pathogens of fish: A review. *Journal of Fish Diseases*, *44*(12), 1883-1900.‏

11. Ali B. Al-Zubaidy . First Record in Yemen of Two Larval Trypanorhynch Cestodes in Commercial Fish (Lethrinus lentjan) from the Red Sea. Vol. 17, pp: 79-87 (2006

12. Williams HH, Jones A, Bray RA. Keys to the cestode parasites of vertebrates: Order Trypanorhyncha Diesing. CABI; 1863.

13. Palm HW, Klimpel S, Walter T. Cestode parasites from the elasmobranchs and teleosts off Queensland, Australia. Parasitol Res 2007;100(3):683–92.

14. Williams HH, McVicar AH. Pathology of helminth and copepod infections of marine fish. Diseases of Fish London: Academic Press 1982;169–200.

15. Williams HH, Jones A. Parasitic worms of fish. London: Taylor & Francis; 1994.

16. Madhavi R, Bray RA. Digenetic Trematodes of Indian Marine Fishes. Springer; 2018.

17. Cribb TH, Bray RA. Marine Fish Trematodes: A Review. Parasitology 2019;146(10):1234–45

18. Bray, R. A., & Justine, J. L. (2016). Hamacreadium cribbi n. sp.(Digenea: Opecoelidae) from Lethrinus miniatus (Forster)(Perciformes: Lethrinidae) from New Caledonian waters. *Systematic Parasitology*, *93*(8), 761-770.‏

19. Woo PTK, Buchmann K. Fish parasites: pathobiology and protection. Wallingford: CABI; 2012.

20- Ali, A. A., Refat, N. A., Mowafy, R. E., Gaheen, S. A., Amer, O. H., & AbdelMageed, M. A. (2024). Pathological studies on some marine fish parasites in Egypt. *Journal of Advanced Veterinary Research*, *14*(3), 379-383.‏

21. Lester RJG, Hayward CJ. Nematode parasites of teleosts. CABI; 2012.

22. Hassan, A., El-Hamidy, S. M., Al-Saud, N., Hassan, S. M., AM, S., Algamdi, K. M., ... & Al-Solami, H. M. Effect of Intestinal Helminths on the Protein Content of Heavy Metals Polluted Tissues of Lethrinus mahsena Fish.

‏23. El-Sayed AFM, El-Ghobashy HA, El-Ghobashy AE. Histopathological changes in the gut of Emperor Fish (Lethrinus spp.) infected with trematodes from the Red Sea. Mar Biol Res 2012;8(3):267–74.

24. Abdel-Hakeem, S. S., Fadladdin, Y. A. J., Khormi, M. A., & Abd-El-Hafeez, H. H. (2024). Modulation of the intestinal mucosal and cell-mediated response against natural helminth infection in the African catfish Clarias gariepinus. *BMC Veterinary Research*, *20*(1), 335.‏

25. Hasan, S. R., Mahdi, B. M., & Azeez, S. T. (2025). Histological Effects of Nematode Infection in the Intestines of Freshwater Fish from the Khasa River in Kirkuk Province, Iraq. *SAR J Pathol Microbiol*, *6*(1), 8-14.‏

26. Bakhraibah, A. O., & BIN DOHAISH, A. J. A. (2023). Histopathological Changes Caused by Parasites in Carangoides Bajad Fish in the Red Sea, Jeddah. *Bulletin of the University of Agricultural Sciences & Veterinary Medicine Cluj-Napoca. Veterinary Medicine*, *80*(1).‏

27- Sakthivel, A., Gopalakrishnan, A., & Selvakumar, P. (2020). Occurrence and pathological studies on acanthocephalan (Neoechinorhynchus agili) infestation in fishes from Tamil Nadu, South-east coast of India. *Journal of Fisheries and Life Sciences*, *5*(1), 38-43.‏

28- El-Hamed, A., Hala, A., & El-Shaer, W. A. (2015). Study on clinicopathological and biochemical changes in some marine water fishes infested with internal parasites in Red Sea. *Egyptian Journal of Chemistry and Environmental Health*, *1*(1), 1017-1031.‏

29. Feist, S. W., & Longshaw, M. (2008). Histopathology of fish parasite infections–importance for populations. *Journal of Fish Biology*, *73*(9), 2143-2160.‏

30- Dezfuli BS, Bo T, Lorenzoni M, Shinn AP, Giari L.(2015). Fine structure and cellular responses at the hostparasite interface in a range of fish-helminth systems. Vet Parasitol;208:272–279. https://doi.org/10.1016/j.vetpar.2015.01.002

1. 31. Kotb HL, Mahdy OA, Shaheed IB. Parasitological and Histopathological Study of Digenetic Trematodes in Mullets from Lake Qarun, Egypt. Glob Vet. 2014;13(2):202-208. doi: 10.5829/idosi.gv.2014.13.02.84102.
2. Bosi G, Maynard BJ, Pironi F, Sayyaf Dezfuli B. Parasites and the neuroendocrine control of fish intestinal function: an ancient struggle between pathogens and host. Parasitology. 2022 Dec;149(14):1842-1861. doi: 10.1017/S0031182022001160.

33. Kim PS, Shin NR, Lee JB, Kim MS, Whon TW, Hyun DW, et al. Host habitat is the major determinant of the gut microbiome of fish. Microbiome 2021;9(1).

31. Talwar C, Nagar S, Lal R, Negi RK. Fish Gut Microbiome: Current Approaches and Future Perspectives. Indian J Microbiol2018;58(4).

32. Negi RK, Lal R. The Effect of Gut Microbiota and Probiotics on Metabolism in Fish and Other Vertebrates. MDPI 2023;12:3016.

33. Egerton S, Culloty S, Whooley J, Stanton C, Ross RP. The gut microbiota of marine fish. Front Microbiol2018;9(MAY).

34. Ghanbari M, Kneifel W, Domig KJ. A new view of the fish gut microbiome: Advances from next-generation sequencing. Aquaculture2015;448.

35. Leroux N, Sylvain FE, Holland A, Luis Val A, Derome N. Gut microbiota of an Amazonian fish in a heterogeneous riverscape: integrating genotype, environment, and parasitic infections. Microbiol Spectr 2023;11(5).

36. Grondin JA, Jamal A, Mowna S, Seto T, Khan WI. Interaction between Intestinal Parasites and the Gut Microbiota: Implications for the Intestinal Immune Response and Host Defense. Pathogens 2024;13(8):608.

37. Bozzi D, Rasmussen JA, Carøe C, Sveier H, Nordøy K, Gilbert MTP, et al. Salmon gut microbiota correlates with disease infection status: potential for monitoring health in farmed animals. Anim Microbiome 2021;3(1).

38. Scheifler M, Magnanou E, Sanchez-Brosseau S, Desdevises Y. Host-microbiota-parasite interactions in two wild sparid fish species, Diplodus annularis and Oblada melanura (Teleostei, Sparidae) over a year: a pilot study. BMC Microbiol 2023;23(1):340.

39. Ulusan Bagci O, Caner A. The interaction of gut microbiota with parasitic protozoa. J Parasit Dis 2021;46:8–11.

40. Brealey JC, Kodama M, Rasmussen JA, Hansen SB, Santos-Bay L, Lecaudey LA, et al. Host–gut microbiota interactions shape parasite infections in farmed Atlantic salmon. mSystems 2024;9(2):e01043-23.

41. Ou W, Yu G, Zhang Y, Mai K. Recent progress in the understanding of the gut microbiota of marine fishes. Mar Life Sci Technol2021;3(4):434–48.

42. Nayak SK. Role of gastrointestinal microbiota in fish. Aquac Res2010;41(11):1553–73.

43. Gómez GD, Balcázar JL. A review on the interactions between gut microbiota and innate immunity of fish. FEMS Immunol Med Microbiol2008;52(2):145–54.

44. Llewellyn MS, Boutin S, Hoseinifar SH, Derome N. Teleost microbiomes: The state of the art in their characterization, manipulation and importance in aquaculture and fisheries. Front Microbiol 2014;5(JUN):207.

45- Sadeghi J, Chaganti SR, Johnson TB, Heath DD. Host species and habitat shape fish-associated bacterial communities: phylosymbiosis between fish and their microbiome. Microbiome 2023;11(1).

46. Al-Rashidi, H. S., & El-Wakil, E. S. (2024). Parasites and Microbiota: Dual Interactions and Therapeutic Perspectives. *Microorganisms*, *12*(10), 2076.‏