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Editorial: Microbial diversity as a prerequisite for resilience and resistance in sustainable aquaculture

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Editorial on the Research Topic
Microbial diversity as a prerequisite for resilience and resistance in sustainable aquaculture

Global aquaculture production has grown by more than 600% in the past three decades and now contributes a nearly equal share of aquatic animals as capture fisheries. In 2020, more than 86 million tonnes of finfish, crustaceans, and mollusks were produced worldwide, valued at over USD 250 billion (FAO, 2022). The continued expansion of the aquaculture industry is beneficial economically, providing jobs and incomes through trade, and socially, providing access to safe and nutritious seafood for the growing human population. However, the sector's growth must not come at the expense of the environment; therefore, innovation is needed to improve aquaculture sustainability.

Recent advances in genomics and bioinformatics have begun unraveling microbial communities' role in animal production. In aquaculture, microbes determine the water quality and contribute to cultured organisms' nutrition, growth, and health (Perry et al., 2020). The interplay between water parameters, the health of the cultured animal, and the presence of pathogens is important for maintaining water quality, preventing disease, and improving output. Preventing and controlling diseases is crucial and may tip the balance between farm success and failure. The conditions in intensive and semi-intensive aquaculture systems can stress animals, and the constant input of nutrients can tip a system towards pathogen proliferation, the combination of which can lead to disease. Importantly, research indicates that a more diverse microbiome can improve the resiliency and health of aquaculture systems (Kim et al., 2022).

Aquaculture requires the input of high-quality feed to maximize nutrition and, therefore, growth. The gastrointestinal microbial populations can improve digestion and nutrient assimilation, reducing the feed conversion ratio (. Microorganisms in the water and biofilms of the system aid in nutrient cycling, degrading excess carbon and nitrogenous waste products, maintaining a safe environment while reducing nutrients in effluents, and preventing deleterious effects on the environment. The host-associated microbiota competitively excludes pathogens while stimulating the host immune system, increasing disease resilience. Over the recent years, novel techniques to establish and maintain a diverse microbiome have been studied to capitalize on these benefits. This Research Topic gathers state-of-the-art studies on microbiomes in the aquaculture environment with novel insights on their importance for the sustainability and resilience of the culture and the potential to use the fundamental data for developing bacterial management protocols.

The need to study the aquaculture environment as a whole has been demonstrated in various studies. This approach is also necessary concerning the aquaculture' microbial world, or 'the holobiome of the aquaculture system' as demonstrated in the review by Gutiérrez-Pérez et al. of scientific literature on Pacific white shrimp, *Litopeneaus vannamei*. This paper provides a comprehensive outline of the knowledge on, and research needs for, aquaculture microbiomes. The importance of studying is emphasized in this review through the need to examine the microbial communities of feed, water, plankton, biofilms, sediments, and host. Moreover, it highlights the existing knowledge gaps concerning the eukaryotic microbiomes and viromes, resistomes, virulence genes, and functional studies. This review reiterates the need to expand the availability of holobiome data and advance bioinformatics capabilities that lead to technological advancements that manipulate these communities for sustainable expansion of the aquaculture industry.

Concerning water quality and fish production, Almeida et al. characterized the microbiomes in rear water, biofilm, and biofilters in recirculating aquaculture systems (RAS) for sole production (*Solea senegalensis*). The study focused on nitrifiers and potentially pathogenic bacterial groups and elucidated the relationships between bacterial groups through the analyses of community networking. Community composition analysis highlighted the high prevalence of nitrifying bacteria in biofilms and biofilters of RAS. Microbial cooperation in nitrogenous waste removal was evident from the community network analysis showing positive associations between ammonia-oxidizing archaea and bacteria and nitrite-oxidizing bacteria. Additionally, the results of this study support previous studies that denote a positive correlation between two potentially pathogenic genera, *Vibrio* and *Tenacibaculum*, which may affect fish health.

The other three original articles explored the effects of different aquaculture strategies, stocking density, feed, and probiotics, on the fish bacterial biota. Clols-Fuentes et al. investigated the water bacterial communities at three locations within RAS for African catfish (*Claria gariepinus*), holding different stocking densities. Interestingly, water harbored the highest diversity and relatively stable dominant phyla at medium stocking densities regardless of sampling location. Potentially pathogenic genera were detected, with the total abundance increasing with fish biomass. The authors suggest that identifying potential reservoirs for fish pathogens may aid in disease prevention. Considering the latter, one preventative mechanism is administering probiotics to stabilize the microbial community and prevent the proliferation of pathogens. These live bacterial supplements can also impact the gastrointestinal bacterial communities of aquatic animals. In their manuscript, Hines et al. described the impacts of a *Bacillus subtilis* probiotic on the culture of steelhead trout, *Oncorhynchus mykiss*. They observed increased bacterial diversity in the gastrointestinal tract when the fish were fed probiotics early in development which was associated with faster growth. However, probiotics administration only in the later life stages negatively impacted growth parameters, which has important implications for production costs and profits. Algal diets also influence the gastrointestinal tract microbiota of fishes, as explored in a study by Ferreira et al. (2022) When European seabass (*Dicentrarchus labrax*) were fed *Gracilaria gracilis* or *Nannochloropsis oceanica*, gut microbiota diversity decreased; however, these impacts were avoided when fish were fed half the concentration of both algae species simultaneously. The inclusion of the algae altered abundances of potentially pathogenic and probiotic bacteria, indicating that diet can influence the microbiota of fishes and therefore impact the sustainability of the aquaculture system.

With this Research Topic, we aim to emphasize the importance of microbial diversity in aquaculture. While there is still much to be learned, we encourage future studies to consider the holobiome of these complex production systems. Due to the importance of microbes to water quality, health, and disease, incorporating technologies that maintain high diversity may play a vital role in the sustainable expansion of the aquaculture industry.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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