Aquatic Ecosystems and Environmental Frontiers, Volume 4, Issue 4, December 2026 *ISSN: 3049-186X*
DOI: https://doi.org/10.70102/AEEF/V4I4/AF260419

Evaluating the Influence of Feed-Derived Organic Matter on Microbial Community Succession in Aquaculture Ponds

[1*] Daan Meijer, Utrecht Institute for Health Technology Research, Utrecht, Netherlands.

[2] Femke Scholten, Utrecht Institute for Health Technology Research, Utrecht, Netherlands.

Abstract: Feed-derived organic matter contributes significantly to nutrient loading in aquaculture ponds through effects on microbial metabolism, water quality, nutrient cycles, and ecological stability. Waste products generated due to uneaten feed and metabolism end up within the pond ecosystem leading to an organic rich environment which impacts the structure of the microbial communities. The reason why such research is required in this situation is due to the increase in the intensification of aquaculture practice together with lack of knowledge regarding feed derived organic matter effects on microbial communities transition in different pond situations. The unique approach of the proposed research is the integration of the organic matter accumulation, physicochemical water quality, sediment properties and the microbial community successions into a comparative ecological assessment study. Water and sediment samples from aquaculture ponds subjected to different organic load will be collected. Seasonal sampling, organic carbon measurement, nutrient analysis, enumeration of microbes and their molecular identification will be done. This study will focus on the variation in bacterial abundance, community diversity, and functional groups of microorganisms responsible for organic matter degradation and transformation processes. The discussion will revolve around the response of microorganisms to enrichment of organic matter, oxygen concentration, and environmental variations. The desired output will be to have better understanding about the effects of organic matter derived from the feed on microbial succession.

Keywords: Feed-Derived Organic Matter; Aquaculture Ponds; Microbial Community Succession; Organic Carbon; Microbial Diversity; Nutrient Cycling; Sediment Microbiology; Aquaculture Water Quality.

(Submitted: September 03, 2026; Revised: October 05, 2026; Accepted: November 23, 2026; Published: December 30, 2026)

I. Introduction

Aquaculture ponds are very significant artificial aquatic ecosystems where fish and shrimp farming is performed in the presence of intricate microbial interactions. The microorganisms are necessary for the decomposition of organic matter, nutrient transformations, water quality maintenance, and overall functioning of the system. Community structure and population sizes of these microorganisms are greatly influenced by environmental factors and the availability of organic and inorganic nutrients. Feed material is an important source of nutrient input into aquaculture systems (Nan et al., 2022; Li et al., 2021). Undigested feed particles, feces, and dissolved organic compounds are released into the pond water and sediments due to intensive feeding (Liu et al., 2025). This is an important source of substrates for microbial activity and affects bacterial metabolism and organic carbon mineralization (Zhao et al., 2020). However, excessive accumulation of organic matter can lead to increased oxygen consumption by the microbes, sedimentation and deteriorating water quality. Microbial succession happens due to change in environmental conditions and substrates availability which affects the population and composition of microorganisms in the system (Yang et al., 2020; Koyama et al., 2020). Consequently, their responses to the growing amount of organic loading might affect the productivity and stability of the ecosystem (Silva et al., 2025). It is essential to recognize the relationship between the feed organic material and microbial successions to achieve better aquaculture management (Song et al., 2025). Seasonality, feeding frequency, oxygen content, temperature, and properties of the sediment can affect the microbial communities' formation. Consequently, the combined assessment of organic matter accumulation and the dynamics of microbial communities is required to assess the changes in the ecosystem of aquaculture ponds (Zhan et al., 2021). In addition to that, higher organic load could help in fostering the growth of certain bacteria species that degrade proteins, lipids, and carbohydrates. Microbial action plays an important role in nutrient cycling

and makes it possible to use the essential nutrients in the pond environment. The variation in the concentration of dissolved oxygen could give rise to different microbial niches especially on the surface and bottom of water ponds; hence, changes in microbial diversity and metabolism. Helpful microbes could play a crucial role in enhancing water quality by degrading the nitrogenous waste material and decreasing the organic load. Excessive microbial decomposition could lead to oxygen deficiency and unfavorable environment conditions.

Problem Statement

As aquaculture intensification increases, there will be the introduction of large amounts of feed-organic matter to the pond ecosystem in the form of feed wastes, fecal matter, and dissolved matter. Such buildup can affect the nutrient status, oxygen levels, sediment properties, and microbial activities in the ponds. While microorganisms play an important role in decomposition and cycling of organic matter, the correlation between the two factors regarding succession of microbial community has not been thoroughly studied in relation to aquaculture ponds. The lack of integrated studies makes it hard to determine the impact that organic matter buildup has on microbial communities.

Research Significance

The current study gives an ecological perspective on how organic material from the feed affects microbial diversity and community formation in fish pond systems. Analysis of microbial response in relation to water and sediment properties will assist in detecting the signs of organic enrichment and improve knowledge about the nutrient cycle.

Organization of the Paper

The study gives an insight into the ecological importance of feed-derived organic matter and its relationship with the formation of the microbial community. In the literature review section, there is an analysis of the concepts of organic enrichment, microbial diversity, and nutrient cycling. At the same time, the weaknesses of existing studies are revealed. The methodology part provides details about the research design, methods of sampling, laboratory analysis, and statistics to be used. Further sections analyze the impact of organic matter and microbial succession.

II. Literature Review

Organic matter produced from feeds forms part of the environmental factors in aquaculture pond systems. It affects the availability of nutrients, microbial metabolism, and sediments in aquaculture. Feed particles and undigested feed, fecal particles, and organic substances in solution affect organic carbon accumulation in water and sediments. Organic compounds act as substrates for the degradation and recycling process by heterotrophic microorganisms. Microorganisms control several biogeochemical processes in aquaculture. Heterotrophic bacteria play a role in the degradation of organic matter, releasing dissolved nutrients which are used in other metabolic reactions. Nitrifying microorganisms convert ammonia to nitrites and nitrates while denitrifying microorganisms facilitate nitrogen removal in favorable environmental conditions. Organic enrichment may change the composition of microbial community in a certain way, through changing substrate availability and environmental conditions. Increase in organic carbon may result in stimulation of growth of heterotrophic bacteria and enhance microbial respiration. The increase in oxygen utilization and decrease in oxygen supply leads to low dissolved oxygen concentration, promoting the development of facultative and anaerobic microorganisms. Sediment properties are also factors affecting microbial communities' formation. The organic carbon concentration, particles properties, moisture, and redox potential affect the formation of microbial habitats and microbial metabolisms. In addition, water temperature, pH, salinity, and dissolved oxygen contribute to the diversity and abundance of microbes. As a result, seasonal differences in feeding habits and pond management may result in temporal differences in microbial communities. From the perspective of existing ecological studies, microbial communities play an important role in the recycling of nutrients and organic matter

decomposition in aquaculture ponds. To understand the process of microbial succession, organic loading, water quality, sediment properties, and microbial community function must be considered simultaneously (Zhang et al., 2024). Moreover, microbial succession may be considered an indicator of changes in the ecosystem health status in the pond based on different feeding practices. Differences in organic matter abundance might impact the diversity, dominance, and activity of microbes. Monitoring the quantity of bacteria, their extracellular enzyme activity, and nutrient turnover rate can show the changes in the microbial process. The interaction of feed and microbial response is crucial for the intensive aquaculture system, as constant organic enrichment might affect the equilibrium of the ecosystem.

Identified Research Gap

While there is evidence regarding the application of organic enrichment and microbes in aquaculture environments, it has not been sufficiently determined how the combination of the organic enrichment through feeding may affect the succession of the microbes within such environment. The correlation between accumulation of organic carbon, changes in concentration of dissolved oxygen, sediment characteristics and functional diversity of microbes should be analyzed. Moreover, temporal change of microbes in different conditions of organic enrichment should also be considered. These questions will be answered by the presented research.

III. Methodology and Proposed Research Architecture

Proposed System Architecture

The suggested framework for research involves the evaluation of feed-derived organic material, sampling of pond water and sediment, physicochemical analysis, microbial identification, and ecological data analysis. The aquaculture ponds will be categorized depending on their organic loadings. Seasonal sampling will be done to determine the dynamics of organic carbon, nutrient levels, dissolved oxygen, and microbial population. Laboratory analysis will be used to identify the types of microbes and their functions. Statistical methods will be used to correlate organic matter accumulation with microbial succession.

Research Workflow Diagram

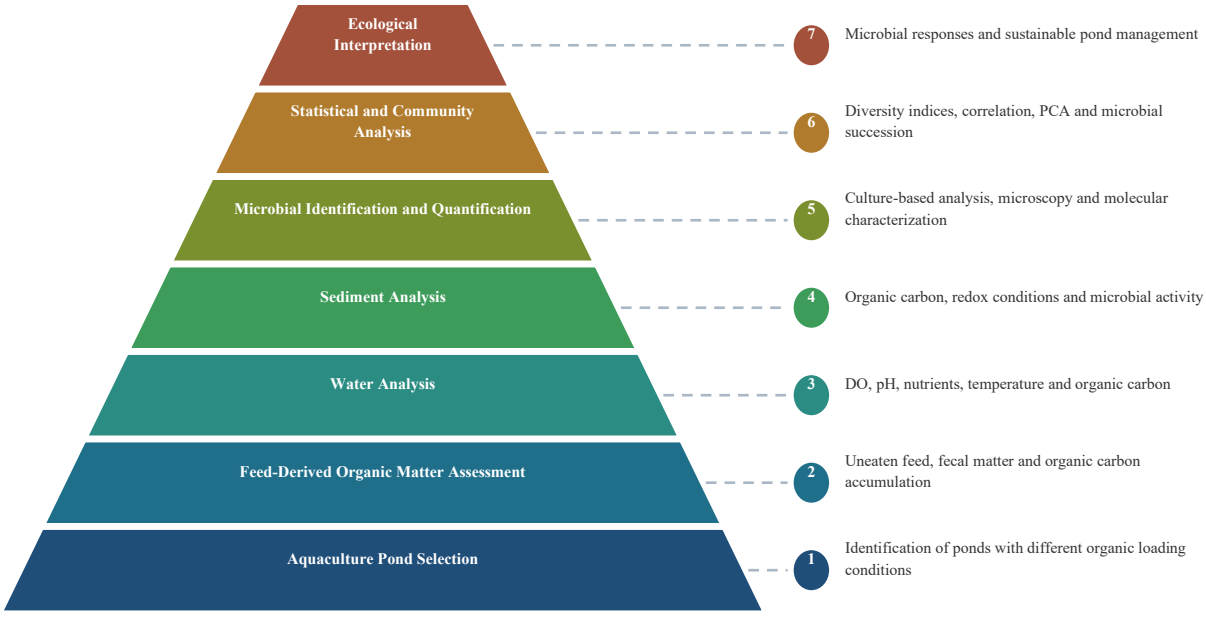


Figure 1: Methodological Architecture for Evaluating Feed-Derived Organic Matter Effects on Microbial Succession

Figure 1 shows the proposed methodological framework to analyze the impact of organic matter derived from the feed on the succession of the microbial community within aquaculture ponds. The methodology starts with the selection of the ponds and analysis of the organic matter. This is then followed by the analysis of water and sediment. Finally, laboratory studies will be conducted to determine the abundance, diversity, and functionality of the microbes.

Study Area Selection and Sampling Design

The experiments shall be carried out in selected aquaculture ponds which have varying degrees of accumulation of organic matter through the use of feeds. The ponds shall be classified according to whether they have low, moderate or high accumulation of organic matter by use of data from feeding, feed conversion data, organic carbon content and sedimentation analysis. Samples of water and sediment shall be taken from the ponds at standard points in the ponds. Sample taking shall include areas near the inlet, central part of the ponds and outlet parts where applicable.

Samples will be taken seasonally for at least a full year in order to examine any temporal variations. Feeding pattern, quantity of feeds used, stocking density and management practices of the ponds will be noted.

Physicochemical and Microbial Analysis

Water quality will be assessed by the parameters such as temperature, pH, dissolved oxygen, electrical conductivity, turbidity, ammonia, nitrite, nitrate, and phosphate. Organic carbon and biochemical oxygen demand will be tested as well, in order to test the presence of organic enrichment and bacterial oxygen consumption.

Total organic carbon, organic matter content, moisture, and redox potential will be determined in sediment samples. These tests will give us insight into the accumulation of organic matter and sediment environment conditions. Bacterial communities will be studied both by enumeration and by molecular identification of bacteria. Heterotrophic bacterial counts will be carried out to determine the number of cultivable bacteria in sediment.

Functional groups of bacteria that participate in carbon oxidation, nitrification, and denitrification will be studied. In addition, the functional genes study might give more insights on nutrient transformations in bacteria.

Statistical Evaluation and Ecological Modelling

The microbial diversity will be measured using Shannon and Simpson indices, while richness of the species or OTU will give insight into complexity of the communities.

The Shannon diversity index will be calculated as:

$$H' = -\sum_{i=1}^{S} p_i \ln(p_i) \qquad (1)$$

Where $p_i$represents the relative abundance of microbial taxon i, and Srepresents the total number of taxa. in equation 1.

The amount of organic material will be tested against microbial quantity and diversity using correlation and regression tests. Either ANOVA or its equivalent will be conducted to test for differences among categories of organic loads. PCA will identify environmental gradients, whereas NMDS will determine the similarities among microbial communities. Appropriate mixed-modeling techniques might be considered to accommodate the seasonality and ponds.

IV. Ecological Influence of Feed-Derived Organic Matter on Aquaculture Microbial Communities

Organic Matter Accumulation and Microbial Activity

Organic matter derived from feed constitutes one of the most significant sources of carbon and nutrients for aquaculture ponds. In the course of intensive feeding, there is always some amount of feed which goes unutilized and sinks at the bottom of the pond ecosystem. Further, there is another source of organic material which enters through feces, mucous production, and metabolic wastes. All these factors contribute to the presence of nutrient-rich conditions in the pond ecosystem. It should be noted that decomposition of organic matter is carried out mainly by heterotrophic microorganisms which utilize organic matter as a source of energy and carbon. Organic materials are broken down into simpler forms and constitute carbon transformations and nutrient recycling. Decomposition might increase microbial biomass and affect the availability of nitrogen, phosphorus, and other nutrients in the pond ecosystem. On the other hand, the excess of organic matter increases microbial oxygen consumption. When the rate of decomposition is fast, dissolved oxygen decreases, especially in the vicinity of the sediment layer where the organic matter accumulates. These environmental changes have the ability to affect the relative abundance of microbial groups. The abundance of aerobic heterotrophic bacteria would be high in the presence of oxygen and the availability of appropriate organic substrates while the abundance of facultative and anaerobic microorganisms would be high under reduced oxygen levels.

The accumulation of organic material will further have effects on sediment composition, redox level, and release of nutrients. Organic material decomposing will lead to the release of ammonium and phosphate which could further affect primary production and nutrient balance in the pond. Thus, feeding-related organic enrichment has positive and negative ecological impacts depending on the amount, nature, and rate of organic decomposition. It is important to understand these processes in order to be able to know how the practice of feeding affects the microbial environment. Additionally, the speed of organic accumulation is dependent on the feeding schedule, type of feed, fish stocking density, and pond maintenance techniques. The accumulation of high-protein feeds is responsible for increasing the levels of nitrogen, while carbohydrate and lipid-containing materials are responsible for increasing the levels of carbon and respiration activities. Also, the constant accumulation of excess feed increases the thickness of the sediment layers, leading to oxygen depletion in such zones. This can affect enzyme production and metabolic functions of various groups of microorganisms. It is important to conduct the analysis of organic carbon content, biochemical oxygen demand, and sediments to understand the degree of organic enrichment.

Microbial Community Succession and Nutrient Transformation

Succession of Microbial Communities is a process wherein changes in microbial composition and abundance over time are brought about by changes in the environment and availability of substrates. In aquaculture ponds, feed organic matter becomes an important ecological driving force for succession in terms of the effects on the carbon source, nutrients, and oxygen status. In the initial stage of accumulation of organic matter, easily degraded materials may become the food for heterotrophic bacteria. With the decrease in substrates, microbial communities could be dominated by those which can use the more complex organic matter. This process could affect the composition and functions of the microbial community. Nitrogen conversion becomes an important part of microbial succession. Organic nitrogenous compounds produced from the decomposition and mineralization of feed could become the substrate for converting into ammonium. With proper oxygen supply, nitrifying microorganisms transform the ammonium into nitrite and finally to nitrate. The biogeochemical cycle of phosphates is also affected by the activity of microorganisms and the characteristics of the sediment. Microorganisms contribute to the mineralization of organic phosphates and have an effect on the concentration of phosphate in the pond environment. These processes may contribute to the regulation of nutrients and productivity of aquatic organisms. Seasonal variation in temperature, intensity of feeding, water renewal, and variations in oxygen levels might have additional effects on the formation of microbial communities. Different patterns of

succession might be observed in ponds with different organic loads. Molecular studies may aid in elucidating the ecological succession of such microbial communities by revealing the taxa and functional groups of bacteria not easily detected by conventional culture-based techniques. Also, the process of microbial succession is characterized by variations in the taxonomical and physiological diversity of microorganisms. Various types of bacteria play roles in carbon breakdown, nitrogen metabolism, and phosphorus cycling depending on environmental conditions. The cooperation between these functional groups ensures the proper availability of nutrients and thus affects the productivity of aquaculture ponds biologically. Differences in microbial activity within the water and sediment zones could be an indication of the oxygen content and organic decomposition rates in the environment. Combining cultivation, molecular analysis, and physicochemical methods will allow getting an integrated view of microbial succession.

Comparative Evaluation of Organic Loading Conditions

A conceptual comparison between the various environments and the properties of microbes in relation to the level of accumulation of organic matter from the feeds can be seen in table 1 below. The table brings out the differences in organic carbon, dissolved oxygen, sediment enrichment, microbial respiration, and nutrient cycling. This is just a conceptual comparison that will guide in understanding microbial succession when there are varying degrees of organic matter loading. The actual microbial numbers should be obtained through scientific tests.

Table 1: Expected Environmental and Microbial Characteristics Under Different Feed-Derived Organic Loading Conditions

Parameters	Low organic loading	Moderate organic loading	High organic loading
Organic carbon	Relatively low	Intermediate	Potentially high
Uneaten feed accumulation	Limited	Moderate	Elevated
Dissolved oxygen	Generally stable	Variable	Greater depletion risk
Microbial respiration	Relatively low	Moderate	Potentially high
Heterotrophic bacteria	Variable	Potentially increased	Potentially elevated
Sediment organic matter	Low	Intermediate	High
Anaerobic activity	Limited	Variable	Greater potential
Nutrient recycling	Moderate	Active	Potentially altered
Microbial diversity	To be evaluated	To be evaluated	To be evaluated

Graphical Representation of Microbial Community Responses

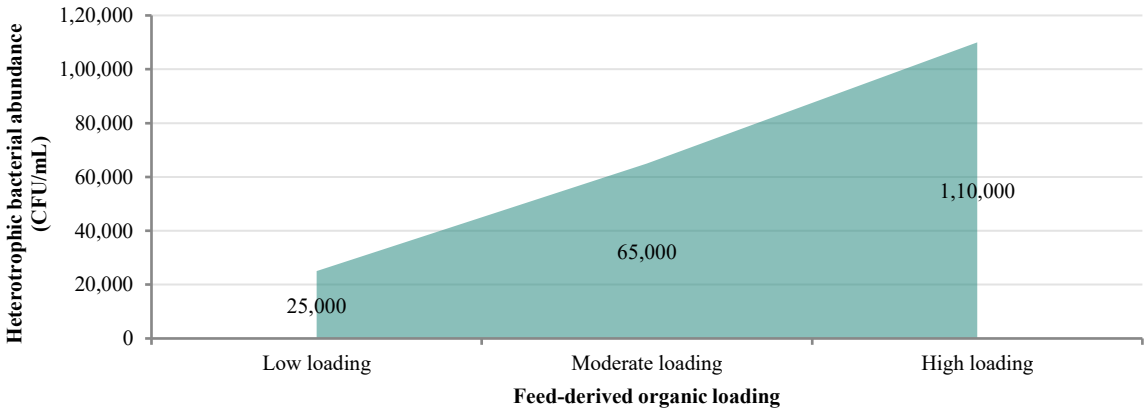


Figure 2: Illustrative Relationship Between Feed-Derived Organic Loading and Heterotrophic Bacterial Abundance

Figure 2 represents the illustration of the assumed comparison between the abundance of heterotrophic bacteria at low, medium, and high organic substrate loading rates from feed. Based on the assumed trend, it is possible that the abundance of bacteria increases when there is an increase in the availability of organic substrates. But an excessively enriched environment may create oxygen limitation in the community.

Discussion

The intended study will offer a holistic understanding of how organic matter from feeds affects microbial succession in aquaculture ponds. Organic enrichment may facilitate heterotrophic bacterial development through enhancing carbon substrate availability; too much may consume oxygen and change the environment in sediments. This may affect microbial diversity and the proportion of microbes engaged in carbon decomposition and nitrogen transformation processes. Temperature variation during different seasons, feeding intensity, and water management may also control microbial succession. Combining physiochemical measurements with microbial identification and multivariate statistics will assist in developing these relationships. It is important to note that excess organic enrichment does not guarantee increased microbial diversity and efficiency of production in the ponds since excess enrichment may create unfavorable conditions. Experimental observation will be needed to confirm these ecological responses.

Future Research Recommendations

The future research in this field should include the incorporation of monitoring that will aid in understanding the microbial succession in relation to varying feeding regimes and seasonal changes in the environment. Advanced molecular methods such as 16S rRNA sequencing and metagenomics can help in improving the identification of the microbes and their functions. The further research in this field could involve the investigation of various types of feeds and their feeding regime on the microbial communities. In addition, the integration of automated water quality monitoring for parameters such as dissolved oxygen and nutrient concentrations could be considered.

Research Challenges

A number of issues could affect the study of feed-based organic material and microbial succession. The differences in the frequency of feeding, the composition of the feed, stocking density, and water exchange rate could make aquaculture ponds different from each other. Seasonal changes in temperature would also make a difference to microbial activity and the breakdown of organic matter. Proper identification of microbes would need a lab that is specialized in this area, along with the necessary machinery and knowledge. Heterogeneity of sediment could also affect measurements of organic carbon and sample collection. In addition to this, proper statistical controls would be needed to differentiate the impacts of organic load from other variables.

Conclusion

The aim of the research is to analyze the impact of organic matter originating from feed on microbial communities' succession in aquaculture ponds. Knowledge about such kind of connection is necessary for revealing ecological consequences of organic enrichment, microbial activity, and nutrients transformation in the aquaculture environment. The uniqueness of the research consists in linking organic matter accumulation, physicochemical parameters of water quality, sediment properties, and microbial succession in a comparative ecological study framework. Such an approach helps to get a more comprehensive idea of the impacts of organic enrichment from feeding activities on microbial communities' composition and functioning. The research methodology includes selection of aquaculture ponds with different organic loads and collection of water and sediment samples in seasonal periods. Calculation of organic carbon, nutrients, dissolved oxygen content, microbial enumeration, and molecular identification will be performed. Statistics will include microbial diversity indices calculation, correlation analysis, principal component analysis, and multivariate community analysis. The research results will help to reveal changes in microbial abundance, diversity, and functional composition at different organic loading levels. The research is also expected to show possible impact of organic carbon accumulation, oxygen content, and sediment enrichment on

microbial succession and nutrient transformation. On the whole, this research provides a scientific basis to understand the impacts of organic matter from feeds on aquaculture pond ecosystems. The conclusions drawn in this research, after their validation through experimental observations, could contribute to better feed management, organic waste management, and sustainable aquaculture practices.

References

[1] Liu, Z., Wang, N., Tan, Y., Liu, Y., Xing, C., Xu, Z., ... & Sun, X. (2025). Seaweed feed enhance the long-term recovery of bacterial community and carbon-nitrogen sequestration in eutrophic coastal wetland. *Journal of Environmental Management*, *379*, 124846. https://doi.org/10.1016/j.jenvman.2025.124846

[2] Song, L., Hu, C., Zhang, X., Liu, Y., Song, G., Wu, J., ... & Sun, M. (2025). Effects of feeding on microbial community structure and pathogen abundance in marine aquaculture ponds. *Marine Environmental Research*, *210*, 107319. https://doi.org/10.1016/j.marenvres.2025.107319

[3] Nan, J., Yang, C., Yu, H., Shi, X., Huang, Q., Huang, J., & Li, J. (2022). Enclosure culture ban and its effects on water quality and phytoplankton community in a subtropical shallow lake. *Aquaculture Research*, *53*(1), 221-231. https://doi.org/10.1111/are.15568

[4] Silva, L., Martinez-Cordero, F. J., Baganz, G., Baganz, D., Hernández-Pérez, A., Coronado, E., & Portella, M. C. (2025). Advancing circularity in small-scale rural aquaponics: Potential routes and research needs. *Resources*, *14*(8), 119. https://doi.org/10.3390/resources14080119

[5] Yang, W., Zhu, J., Zheng, C., Lukwambe, B., Nicholaus, R., Lu, K., & Zheng, Z. (2020). Succession of phytoplankton community during intensive shrimp (Litopenaeus vannamei) cultivation and its effects on cultivation systems. *Aquaculture*, *520*, 734733. https://doi.org/10.1016/j.aquaculture.2019.734733

[6] Zhao, Z., Jiang, J., Pan, Y., Dong, Y., Chen, Z., Zhang, G., ... & Zhou, Z. (2020). Temporal dynamics of bacterial communities in the water and sediments of sea cucumber (Apostichopus japonicus) culture ponds. *Aquaculture*, *528*, 735498. https://doi.org/10.1016/j.aquaculture.2020.735498

[7] Koyama, M., Nagao, N., Syukri, F., Abd Rahim, A., Toda, T., Tran, Q. N. M., & Nakasaki, K. (2020). Ammonia recovery and microbial community succession during thermophilic composting of shrimp pond sludge at different sludge properties. *Journal of Cleaner Production*, *251*, 119718. https://doi.org/10.1016/j.jclepro.2019.119718

[8] Zhang, Y., Ai, D., Liu, K., Sun, S., Li, Y., Huang, D., & Zhang, J. (2024). Microbial succession and enrichment of antibiotic resistance genes during algal-bacterial biofilm purification of aquaculture wastewater. *Journal of Water Process Engineering*, *64*, 105642. https://doi.org/10.1016/j.jwpe.2024.105642

[9] Li, X., Liu, L., Zhu, Y., Zhu, T., Wu, X., & Yang, D. (2021). Microbial community structure and its driving environmental factors in black carp (Mylopharyngodon piceus) aquaculture pond. *Water*, *13*(21), 3089. https://doi.org/10.3390/w13213089

[10] Zhan, P., Li, L., Tang, C., Yang, P., Hu, H., Penuelas, J., & Tong, C. (2021). Successional patterns of bacterial communities and their functions in shrimp aquaculture pond water across farming phases. *Aquaculture Research*, *52*(12), 6322-6337. https://doi.org/10.1111/are.15496