ULST Timisoara

Multidisciplinary Conference on Sustainable Development

15-16 May 2025

INTEGRATED MULTI-TROPHIC AQUACULTURE IN THE CONTEXT OF THE CIRCULAR ECONOMY - REVIEW

Sandra Mihailov, Silvia Pătruică, Grozea Adrian*

Affiliation: University of Life Sciences „King Mihai I" from Timişoara, Faculty of Bioengineering of Animal Resources

*Corresponding author's email: adriangrozea@usvt.ro

Abstract

Aquaculture is among the fastest-growing industries worldwide, playing a key role in feeding a continuously expanding global population. This accelerated development calls for the adopting of innovative technologies, efficient culture systems, and sustainable production practices. In this context, recirculating aquaculture systems (RAS) are considered a strategic solution for meeting the increasing demand for aquatic products, thanks to their capacity to optimize resource use and reduce environmental pressure. Additionally, the integration of new and adaptable species into Integrated Multi-Trophic Aquaculture (IMTA) or aquaponic systems, especially in freshwater environments, significantly enhances the efficiency and sustainability of modern aquaculture. Integrating IMTA into RAS enables efficient water use, more rigorous biosecurity control, and a significant reduction in nutrient emissions. Moreover, incorporating hydroponic components enhances the benefits of these systems by allowing the cultivation of edible plants that utilize residual nutrients and contribute to strengthening the circular nature of the system. Through resource valorisation, waste reduction, and production diversification, IMTA emerges as a key model for modern, sustainable, and responsible aquaculture, with a positive impact on ecosystem health and global food security. This review synthesizes the most recent research on IMTA in fresh water, highlighting its potential in the transition towards sustainable aquaculture, in full alignment with the principles of the circular economy. IMTA involves the co-cultivation of species from different trophic levels within a system that transforms organic and inorganic waste into valuable resources for other cultured organisms. This model optimizes nutrients use, reduces environmental impact, and diversifies production, while also offering additional economic opportunities.

Keywords: Integrated Multi-Trophic Aquaculture; circular economy; recirculating aquaculture system

Diversifying Aquaculture Production through IMTA

Co-cultivation of Species at Different Trophic Levels

Aquaponic systems reduces effluent discharge, optimizes water and energy reuse, minimizes fertilizer input (up to 50%), and supports sustainable, climate-resilient circular aquaculture. (Azhar et al., 2023; Endut et al., 2011; Jones et al., 2022; Vergote et al., 2012; Zimmermann et al., 2022)

IMTA systems integrating fish and crustaceans enhance nutrient recovery, reduce organic waste accumulation, improve system self-cleaning efficiency, increase total biomass yield, and support the production of multiple outputs from a single feed input. (Azhar et al., 2020, 2023; Goda et al., 2024; Hisano et al., 2019; Knowler et al., 2020; Peter Edwards, 2015; Roessler et al., 2019; Zimmermann et al., 2022)

e.g. tilapia, catfish, bass, carp, pikeperch, rainbow trout, rohu

co-culture

e.g. lettuce, tomatoes, water spinach, Lemna , Azolla, mentha aquatica

co-culture

e.g. crayfish, giant freshwater prawns, amazon river prawn

lettuce, pak choi

co-culture

co-culture

co-culture

e.g. largemouth bass, gibel carp, bighead carp

e.g. Diplodon chilensis

e.g. Lettuce, Lemna

e.g. freshwater mussels, bivalves

Aquaponic systems enhances nutrient recycling (up to 82% N, 80% P), stabilizes water parameters, and provides ecosystem services such as carbon sequestration and pollution reduction. (Azhar et al. 2023; Bable et al., 2024; Bakhsh et al., 2011, 2012; Blidariu et al., 2011; Chopin et al., 2016; Edwards P., 2015; Endut et al., 2011; Goda et al., 2024; Knowler et al., 2020; Nissar et al., 2023; O'Neill et al., 2022; Popp et al., 2018)

IMTA systems integrating fish, crustaceans, and plants promote stable nutrient cycling, reduce organic waste accumulation, enhance plant biomass production, and improve feed conversion efficiency. (Sace et al. 2013)

IMTA systems that integrate fish, plants, and mollusks contribute to improved water quality, enhanced fish immunity and survival, and a significant reduction in pathogenic bacteria (up to 98%). Additionally, they promote nutrient recycling, facilitate bioremediation and biomass conversion, and support a diversified and ecologically balanced production. (Azhar et al., 2023; Bable et al., 2024; Goda et al., 2024; Honghua Shi et al., 2013; Knowler et al., 2020; Nissar et al., 2023; Sicuro et al., 2020; Yunmeng Li et al., 2018)

Fish polyculture optimizes trophic space use, reduces interspecific competition, improves water quality, and leads to higher yields compared to monoculture by balancing trophic interactions and enhancing overall system performance. (Edwards P., 2015; Popp et al., 2018; Yunmeng Li et al., 2018; Zimmermann et al., 2022)

In IMTA systems, freshwater mussels (Diplodon chilensis) improve water quality by reducing chlorophyll a, phosphate, and ammonia levels in fish tanks (Granada et al., 2016; Nissar et al., 2023)

Increasing the sustainability of aquaculture through IMTA

• *Reducing Environmental Impact*

Freshwater IMTA systems significantly reduce the ecological footprint of aquaculture by promoting nutrient recycling and minimizing organic and microbial pollution. Co-cultivated species act as biological filters, while freshwater bivalves effectively reduce pathogenic bacteria, including Aeromonas hydrophila. Constructed wetlands with aquatic plants contribute to natural water purification and improved dissolved oxygen levels. (Aje G.S. et al. 2022; Benedetto S. et al. 2020; Endut A. et al. 2011; Mahmud H.A. et al. 2023)

• *Diversification and Economic Stability*

Integrated Multi-Trophic Aquaculture (IMTA) supports economic diversification by enabling the co-culture of complementary species such as fish, microalgae, and filter feeders. Such systems improve nutrient utilization and have the potential to enhance overall resource efficiency and market adaptability. (Meng Li et al. 2019)

•*Increasing Resource Efficiency*

Integrated Multi-Trophic Aquaculture (IMTA) enhances resource efficiency by capturing residual nutrients and converting waste into valuable biomass. The integration of fish, aquatic plants, macroalgae, molluscs, and crustaceans in recirculating systems promotes high nitrogen and phosphorus retention while optimizing water use. (Granada Luana et al. 2018; Yunmeng Li et al, 2019)

• *Added Value Through By-product*

IMTA generates additional economic value by recovering and utilizing by-products such as algae, bivalve shells, plant biomass, and organic sediments. These can be used in nutrition, cosmetics, biofertilizers, or feed, supporting waste reduction and value chain diversification. (Checa D. et al. 2024)

• *Increased Social Acceptability*

Integrated Multi-Trophic Aquaculture (IMTA) is perceived by consumers as a sustainable and eco-friendly production method, especially when accompanied by credible eco-labeling and transparent communication. These elements enhance consumer trust, support product differentiation, and help address public concerns about environmental impact and animal welfare in aquaculture. (Alexander K.A. et al. 2016; Themistoklis A. et al. 2025)

• *Contribution to SDGs and Global Sustainability*

Integrated Multi-Trophic Aquaculture (IMTA) contributes meaningfully to the Sustainable Development Goals, particularly SDG 12 (Responsible Consumption and Production) and SDG 14 (Life Below Water), by minimizing environmental pollution, enhancing nutrient recycling, and fostering circular bioeconomy practices. IMTA represents a scalable and sustainable model for the future of aquatic food systems. (Checa D. et al. 2024; Rusco G. et al. 2024)