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INTEGRATED MULTI-TROPHIC AQUACULTURE SYSTEMS (IMTA): A SUSTAINABLE APPROACH FOR BETTER RESOURCE UTILIZATION

Lokesh Pawar[1]*, Mayuri Nag[2] and M. Junaid Sidiq[3]

[1]College of Fisheries (Central Agricultural University - Imphal), Agartala, Tripura, India 799210

[2]College of Fisheries, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India 263145

[3]ICAR - Central Institute of Fisheries Education, Mumbai, Maharashtra, India 400061

**Corresponding author: pawarlokesh2405@gmail.com*

For hundreds of people worldwide, fishing and aquaculture continue to be vital sources of food, nutrition, revenue, and livelihoods. The development of innovative culture techniques and the enhancement of culture systems for the blue revolution are products of the expansion of the fisheries and aquaculture industries. Integrated Multi-trophic Aquaculture (IMTA) is one such system. IMTA is an intense and synergistic cultivation of numerous species inhabiting different trophic levels of the water column. One species' waste becomes a valuable resource for another aquatic species. By turning leftovers and uneaten feed from fed organisms into harvestable crops, IMTA encourages economic viability and increases ecological sustainability. Also, it has been the subject of several initiatives in numerous nations. This article is a brief description of the IMTA, its design, and relevance to sustainability.

Keywords: Integrated Multi-trophic Aquaculture; IMTA; Sustainable Aquaculture; Bio-mitigation; Culture System

INTRODUCTION

In recent times, aquaculture has emerged as one of the major providers of food security throughout the world. Since the past decade, aquaculture has supplied over half of the fish consumed globally (FAO, 2016). In regions of Africa, Asia, Latin America, and the Caribbean where population growth has been increasing, aquaculture seems to grow relatively faster. Along with rising production, the demand for practitioners of integrated multi-trophic aquaculture is also increasing. This system, integrated multi-trophic aquaculture, abbreviated as IMTA, borrows a concept from nature, where in the food chain; an organism of a particular species always finds a feeding niche in the waste produced by organisms of another species. IMTA involves farming multiple aquatic species from different trophic levels in an integrated fashion so as to increase the efficiency of the system, reduce the produced waste, and provide bio-remediation-like ecosystem services. Integrated multi-trophic aquaculture has now been the focus of research worldwide, as it holds the potential to make aquaculture profitable and more sustainable in all freshwater, brackish water, and marine water systems.

What is IMTA?

Pond aquaculture is the major system being commercialized because of its higher productivity and ease of management. It generates a large profit in a short period of time. Commercialization shifts the cultural system from extensive to semi-intensive to intensive. High levels of feed application in small volumes of water, combined with a higher stocking density, cause issues such as faecal matter and waste accumulation on the pond bottom in commercial aquaculture systems. The rapid decomposition of waste deteriorates water quality, affecting cultured fish species and causing diseases and mortality conditions. Solutions to the problem include the removal of pond bottom soil containing decomposed waste and the continuous exchange of water. This makes cultural practices more labor- and money-intensive, and they also consume a lot of time, which makes the business unprofitable. Integrated multi-trophic aquaculture (IMTA), which serves as a huge solution to this challenge that farmers face, is a low-cost technology that works in a sustainable way (Ridler *et al.,* 2007; Costa-Pierce, 2010). Contrary to finfish polyculture techniques, which assign the same biological and chemical processes to the fish and might cause unforeseen ecosystem shifts, IMTA is not to be mistaken with polyculture. Multi-trophic refers to the practice of integrating organisms from several trophic levels into a single system for cultivation. By combining the multi-trophic sub-systems, IMTA enables continuous fertilizer and energy transfer through water, enabling closer cultivation of diverse species (Sasikumar and Viji, 2015) as described in figure 1.

SYSTEM DESIGN

In order for both particulate and dissolved waste products produced by fish farms to be captured and used, several components and/or species must be chosen, arranged, and placed in the system. The system layout and species used should be developed to optimize waste product recapture. For instance, in the marine environment, bottom feeders like sea urchins and sea cucumbers may use and consume bigger organic debris, such as uneaten feed and faeces, which sink below the cage system. In the water column, filter-feeding organisms like oysters, mussels, and scallops remove tiny suspended particulate debris. The seaweeds are positioned in the direction of water flow, a bit further from the site, and assist in removing some of the inorganic dissolved nutrients from the water, such as phosphate and nitrogen. The species raised in IMTA should be commercially viable as aquaculture products and grown at densities that maximize waste material absorption and use throughout the production cycle (Sasikumar and Viji, 2015). IMTA involves culturing fed aquaculture species (e.g., finfish and shrimp) with extractive species that utilize the organic (from shellfish and herbivorous fish) and inorganic (from seaweed) wastes from the system for their growth, and this creates a balance between systems for environmental sustainability (biomitigation), social acceptability with better management practices, and economic stability that provides product diversification and risk reduction (Barrington, 2009; Johnson, 2018).

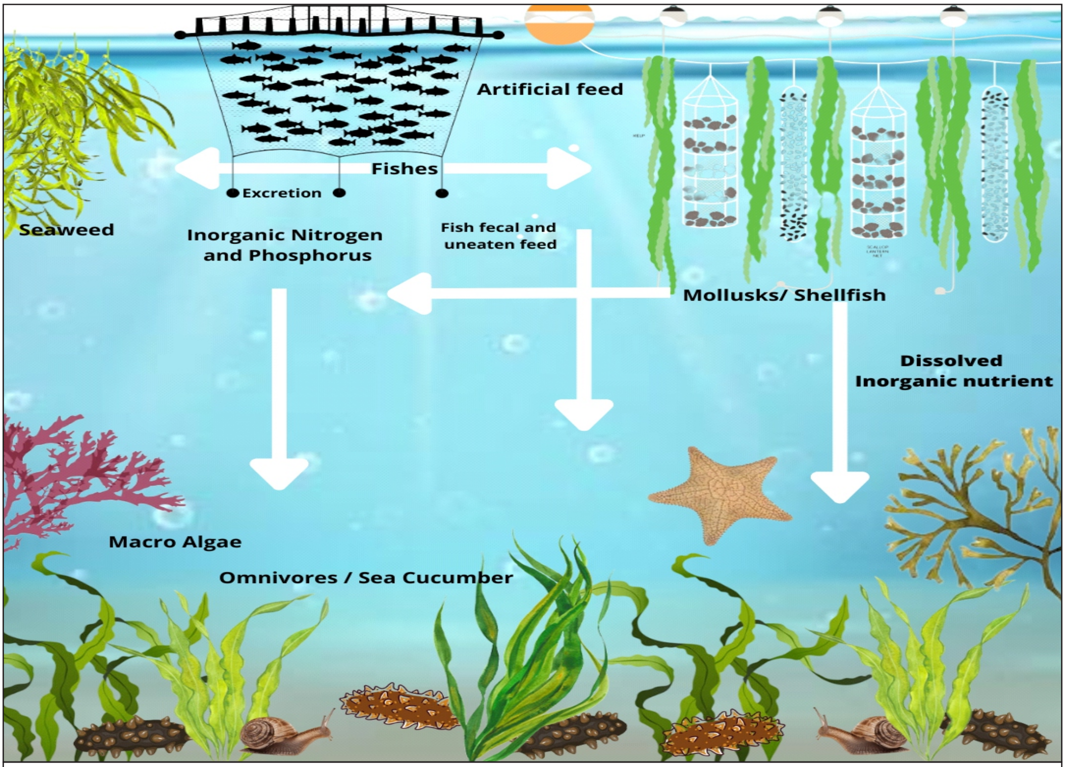

Fig. 1 Integrated Multi-Tropic Aquaculture model

IMTA AND SUSTAINABILITY

The depleting fish stocks pose a significant problem for the fisheries sector at present and will remain so in the future as well. Sustainability in aquaculture will alleviate the stress that the rapidly growing human population is having on natural resources and the environment. Moreover, there are still some issues that aquaculture systems face that are associated with waste production and sustainability. Integrated multi-trophic aquaculture plays a major role in reducing this stress as it combines traditional fish farming with another species at a different trophic level, which enables the utilization of waste by the another species. Many commercial aquaculture systems require a very large input and generate massive amounts of waste.

The primary objective of sustainability is to minimize inputs and outputs. The problem with traditional aquaculture systems is the scarcity of fishmeal, which is required to produce fish feed. However, seaweed may be used in its place since it is an excellent source of protein and other components without increasing the cost, and utilizing it can also lessen the need for fertilizer and irrigation (Chopin, 2012). The extra nutrients can be used by seaweed, which will then turn them into biomass. Dr. Thierry Chopin asserts that "the solution to nitrification is conversion within an eco-system-based management viewpoint, not dilution" (Chopin, 2008). Integrated multi-trophic aquaculture promotes environmental and economic sustainability by converting uneaten feed and byproducts from fed organisms into harvestable crops, ultimately reducing eutrophication and the failures of aquaculture systems. It also directly assists us in achieving several global sustainable development goals (SDGs), especially those described in figure 2, by ensuring food security, reducing poverty, fostering economic development, preserving the ecosystem, and boosting biodiversity, IMTA can help the United Nations Sustainable Development Goals (SDGs) be reached. First, by providing local communities with employment options and a revenue stream, it can support SDG 1: No Poverty. By giving local populations a sustainable supply of sustenance, IMTA can also support SDG 2: Zero Hunger. By fostering employment possibilities and promoting economic growth in rural and coastal regions, IMTA can support SDG 8: Decent Work and Economic Growth. Second, by lowering waste and emissions, IMTA can support SDG 12: Responsible Consumption and Production. By utilising the waste of one species as a supply of nutrients for another species, IMTA can lessen the environmental effect of aquaculture. Because less external sources, such as fish feed, are required in this approach, aquaculture has a smaller negative effect on the ecosystem (Chopin *et al.,* 2017).

Lastly, by lowering greenhouse gas pollution, IMTA can support SDG 13: Climate Action. By utilising the waste of one species as a supply of nutrients for another species, IMTA can lessen the environmental effect of aquaculture. By reducing the need for external sources like fish feed, this strategy lowers greenhouse gas pollution. Fourthly, IMTA can contribute to SDG 14: Life Below Water by reducing the environmental impact of aquaculture. IMTA can reduce the impact of aquaculture on the marine environment by reducing waste and pollution. IMTA can also enhance biodiversity by creating a habitat for different species to coexist (Mozaffarian *et al*., 2020; Sultana *et al*., 2021).

Fig. 2. IMTA having direct impact on SDGs

BENEFITS ASSOCIATED WITH IMTA

- Effluent bio-mitigation involves reducing effluents by using bio-filters that are compatible for the biological niche of the aquaculture site. Many of the environmental issues caused by monoculture aquaculture may be resolved by doing this. Effluent reduction through the use of bio-filters (bio-mitigation) (Petrell and Alie 1996; Troell *et al*., 2009)
- An overall increase in the economy by exploiting the extractive capacities of species from different trophic levels. The waste in the integrated multi-trophic aquaculture systems is considered a resource for the culture of bio-filters.
- Increase in employment at local levels (Barrington, 2010).
- Disease prevention or reduction by certain extractive species, such as seaweed, due to their antibacterial properties against fish pathogenic bacteria.
- Increased profits by obtaining eco-labelling and organic certification programs (Sasikumar and Viji 2015).
- IMTA substantively decreases the environmental cost of aquaculture and increases the assimilative capacity of the farm (Knowler *et al*., 2020).

GLOBAL STATUS OF IMTA

The countries having IMTA systems on a near commercial scale are China, Chile, Canada, South Africa, Ireland, Scotland, the United Kingdom of Great Britain, and the United States of America. Whereas, ongoing research related to the development of IMTA are being conducted in Portugal, Spain, and France. The Scandinavian countries, specifically Norway, despite having a large finfish aquaculture network, have laid some groundwork towards the development of IMTA (Barrington *et al*., 2009). For the past fifteen years, research on the co-culture of marine fish and seaweed have been conducted in nations like Japan, Canada, New Zealand, Chile, Scotland, and the USA. Numerous nations, including Australia, France, Canada, the United States, Chile, and Spain, have also examined the use of oysters and mussels as bio-filters in fish farming systems. On Canada's east coast, at several locations in the Bay of Fundy, IMTA studies have been conducted. Here, kelp (*Alaria esculenta, Saccharina latissima*), blue mussels (*Mytilus edulis*), and Atlantic salmon (Salmo salar) were all raised together. The study found that growing kelp and mussels close to fish farms resulted in output increases of 46 to 50% (Wong, 2018; Carras *et al.,* 2019;). In China, *Gracilaria lemaneiformis* seaweed increased its density from 11.16 to 2025 g/m2 over a 3-month growing period when cultivated across 5 km of culture ropes in close proximity to fish net cages on rafts.

In India, IMTA in the open sea is a very recent approach. A combination of fish and species of prawns in a culture system is considered useful as it yields good production and effectively utilizes the available ecological niches of the pond system (Uddin, 2018). Similarly, the culture of Indian shrimp kept in cages with bivalves resulted in higher growth and survival rates in the cages. Cultivating *Gracilaria* sp. with shrimp (*Fenneropenaeus indicus*) resulted in nutrient extraction from shrimp culture waste by the seaweed. 600 g of seaweed was able to remove 14% of the phosphate, 25% of the ammonia, and 22% of the nitrate from 200 g of shrimp waste. Furthermore, the use of IMTA in open sea cage farming systems of the fish *Rachycentron canadum* on the eastern coast increased seaweed production by 50%, *Kappaphycu salvarezii*. In Karnataka, open sea mariculture of finfishes with integration, along with raft culture of green mussels, *P. viridis*, showed a slight reduction in nutrients (Sasikumar and Viji, 2015).

The IMTA model includes Mullets (*Mugil cephalus*), *Liza parsia*, and Tiger Shrimp. In the Sundarbans of West Bengal, India, it developed into a successful aquaculture technique as a fed-species with the estuarine oyster, *Penaeus monodon*. Here was the first use of estuarine oysters as an extractive species in the brackishwater IMTA system. The IMTA system could produce more mullets per unit time. In comparison to the control system, the IMTA significantly increased net income by 69% and the benefit-cost ratio by 30% (Biswas *et al*., 2019).

CONCLUSION

In the current scenario, the monoculture system appears to be slowing down due to high input costs, resulting in the prevalence of IMTA. The integrated multi-trophic aquaculture system has good environmental stability and few to no socioeconomic concerns. IMTA provides profitability in the production system as all aspects of the system work as a resource for its corresponding niche or trophic level. So, it is right to say that adoption of IMTA could lead to higher productivity and better utilization of resources. Stakeholders could get more incentive if they integrated the culture system like that of IMTA.

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