# Integrated Multi-Trophic Aquaculture

Supreet Kaur
College of Fisheries, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana
Email- ksupreet2906@gmail.com

Food demand is rising due to the world's expanding population. In the past two to three decades, the aquaculture industry has made substantial advances despite population growth, advancements in human welfare, and a decline in natural aquatic resources (Tang *et al.,* 2024). Biofilter organisms from the different trophic levels in the aquaculture plant are used in an integrated multi-trophic aquaculture (IMTA) system to remove animal waste from the water. Through an ecosystem-oriented methodology, the IMTA aims to improve sustainability in intensive aquaculture by combining fed aquaculture species with both organic and inorganic extractive species to create an equilibrium system that promotes social acceptance, financial viability, and environmental sustainability (Biswas *et al.,* 2020; Sanz-Lazaro and Sanchez-Jerez, 2020). The IMTA technique was created to use excess nutrients from organisms at a higher trophic level to generate economically valuable lower trophic level commodities. The IMTA systems provide the best possible answer to the problems aquaculture faces, such as resource inefficiency, environmental contamination, aquaculture hazards, and model development obstacles. Thus, the application of IMTA systems in aquaculture is highly recommended (Troell *et al.,* 2009; Zhang *et al.,* 2022). The three primary issues facing aquaculture—pollution, feed input, and space—are addressed by IMTA. According to Chopin et al. (2001; Troell *et al.,* 2003) integrated multi-trophic aquaculture (IMTA) is the practice of cultivating aquatic species of varying trophic levels close to one another in a way that recycles waste, by-products, or uneaten feed from one species and uses it as energy, fertilizer, or feed for another crop. This allows the crops to benefit from their synergistic interactions. A standard IMTA configuration consists of three main parts (Troell *et al.,* 2009):

1. Fed aquaculture species (finfish/shrimp) - Finfish contribute to the economy of an IMTA setup, form the upper trophic level, and provide nutrients to other system components (Sasikumar and Viji, 2015). A viable IMTA is likely to have a predatory finfish as a fed species, but the choice of fed aquaculture species is only chosen after a thorough economic, environmental, and dietary review. Carp, a lower trophic level fish, are more energy efficient than salmon, a top predatory fish, yet salmon has higher feed requirements and eventually excretes more nutrients.

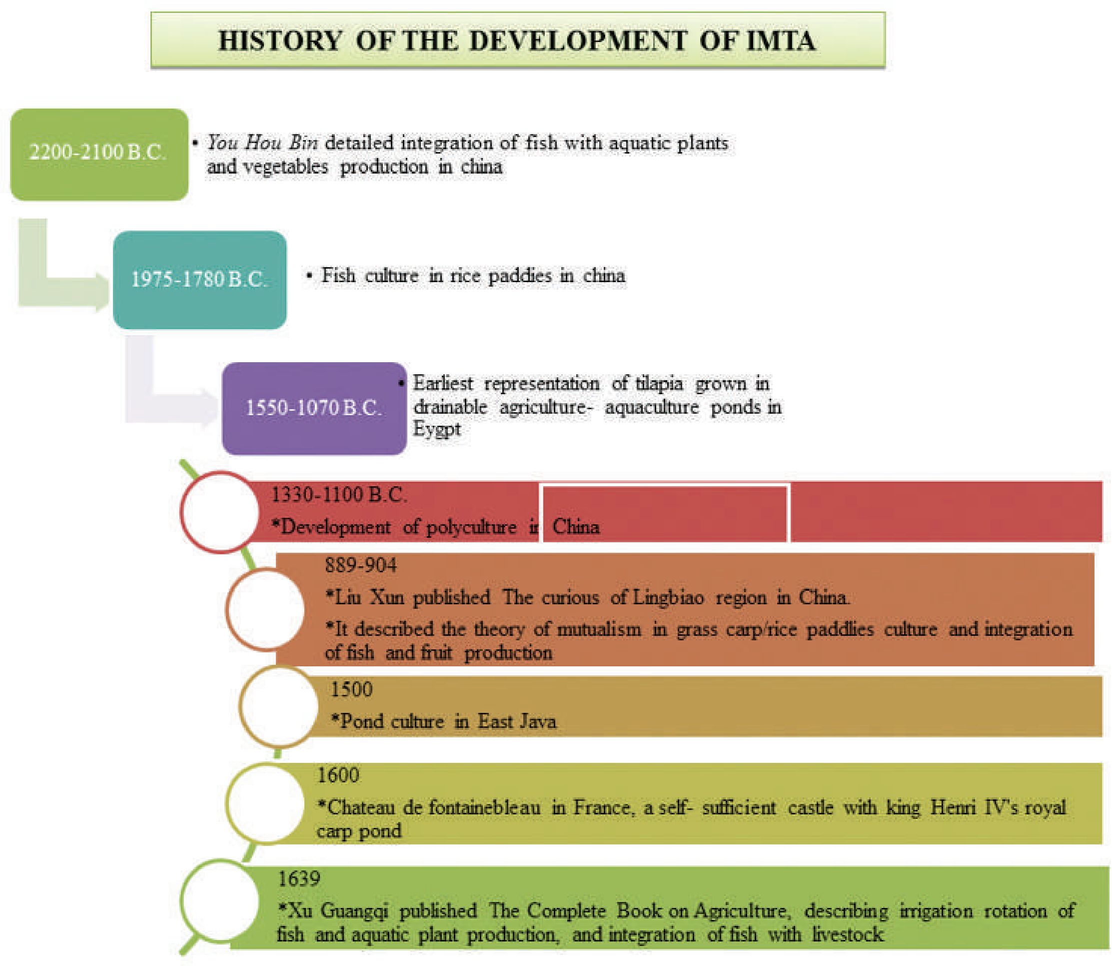
2. Inorganic extractive species (seaweeds)- Since algae are an essential part of IMTA because of their capacity to absorb nutrients, the selection of algae should be based on their capacity to eliminate phosphate and nitrogen in addition to their ideal temperature range (Skriptsova and Miroshnikova, 2011). Along the Atlantic coast, it has been common practice to use *Gracilaria bursa-pastoris, G. gracilis, Chondrus crispus, Palmaria palmata, Porphyra dioica, Asparagopsis armata, Gracilariopsis longissima, Ulva rotundata,* and *U. intestinalis* as biofilters in conjunction with sea bass and turbot (Barrington *et al.,* 2009). Algal growth modeling in the finfish-sea urchin-seaweed system showed that nutrients, radiation, and ambient temperature typically operate as growth-limiting factors. Temperature and radiation shouldn't be limiting considerations in an algae farm; instead, nutrients could be one (Lamprianidou *et al.,* 2015).

3. Organic extractive species (suspension and deposit feeders)- Many organisms, such as crustaceans and echinoderms, have been tested for their suitability for open water IMTA setups ( Barrington *et al.,* 2009; Nelson *et al.,* 2012). However, macroalgae and bivalves have been found to be suitable for the setup because they are grown in the down current area of fed aquaculture cages, which makes it easier for farm waste to flow towards these suspension extractive species or SES. There are two primary types of organisms in the SES group: bivalves, which use organic waste, and macroalgae, which use inorganic waste. Particulate fish waste serves as an extra food source for suspension-feeding bivalves, which are generalist consumers that take a wide variety of particles of various sizes and types ( Troell *et al.,* 2003). Echinoderms are the top prospect for the deposit extractive species, which is the group that occupies the

bottom of the culture site. The garbage that the suspension feeders miss is what they eat.

### Evolution of IMTA

Modern IMTA, also known as Polyculture, emerged gradually over a long period of time, starting with integrated fish farming through polyculture and ultimately incorporating ecological engineering into aquaculture. The organic and inorganic extractive aquaculture species (bivalves, aquatic plants) and the fed-aquaculture organisms (fish, shrimp) are grown independently in designated production units in intensive monoculture or polyculture systems, which clearly result in notable environmental changes. IMTA involves the cultivation of fed species that require nourishment from feed supplementation, while extractive species utilize the organic and inorganic waste generated in the production unit for maintenance and growth metabolisms. A deeper understanding of IMTA principles and practices is crucial to the creation of harmonious systems that support ecological sustainability (by mitigation), financial viability (through diversified products and risk elimination), and social acceptance (via improved management procedures) (Pinak *et al.*, 2023). From a conceptual standpoint, the IMTA is




| | |
|---|---|
| **John ryther et al., 1975** | Integrated waste recycling marine polyculture systems |
| **Marilyn Harlin et al., 1979** | Seaweeds in closed system fish culture |
| **M.E. McDonald, 1985** | Biological removal of nutrients in algal fish systems |
| **Amir Neori, 1991** | Seaweed biofilters for intensive mariculture |
| **Muki Shpigel et al., 1991** | Oysters in fish aquaculture ponds |
| **Alejandro Buschmann et al., 1994** | Seaweed cultivation with land-based salmon effluents |
| **Max Troell et al., 1999** | Aquaculture ecological engineering |
| **Thierry Chopin and Jack Taylor, 2004** | Integrated multi-trophic aquaculture |

an evolving agricultural method that entails growing two or more organisms together while taking into account the trophic levels, feeding preferences, and recycling by-products from one species as inputs for another.

### Selection criteria for species

IMTA prioritizes environmental sustainability, which influences the selection criterion for species. Because of this, the selection of species is determined by an understanding of the constraints that are inherent in the natural ecosystem. It is crucial to carefully assess each species' compatibility with the particular habitat and culture unit when deciding which ones are appropriate for incorporation inside an IMTA system. Farmers must understand the compatibility of the species and its possible impacts on the ecosystem in order to guarantee both good growth and economic viability. For nutrition, organisms that need to be fed—such as carnivorous fish and shrimp—rely on outside supplies like pellets or abandoned fish. On the other hand, organisms that are extractive obtain their nourishment from their surroundings. This includes seaweed and bivalves, two economically important cultural groups. Carefully choosing co-cultured species combinations requires consideration of a number of factors and situations.

1. Complementary functions in the system with other species: On various levels of trophic structure, select species that are complementary to one another. To enhance water quality and promote efficient growth, for instance, newly integrated species need to be able to consume the waste products of other species.

2. Adaptability with regard to the habitat: Native species can be utilized for which technology is accessible and within their typical geographic range.

3. The possibility that invasive species will damage the surrounding ecosystem and possibly interfere with other commercial endeavors. Moreover, native species have developed strong adaptations to the local environment.

4. Culture technologies and site environmental conditions: When selecting a farm site, particulate organic matter, dissolved inorganic nutrients, and particle size range should all be taken into account.

5. Utilize species that can produce a sizable biomass in order to mitigate problems effectively and continuously. Another possibility is to have a species that is highly valuable, in which case smaller volumes can be produced. Nevertheless, the latter lessens the bio mitigating role.

6. Pricing and market demand for the species as a raw material or for products made from these organisms: Make use of species whose market worth is known or thought to exist.

7. Potential for commercialization: Make use of species for which legislators and regulators will allow the exploration of new markets without putting further regulatory barriers in the way of commercialization.

8. Contribution to enhanced environmental performance

### Benefits and challenges of IMTA

One advantage of IMTA is that it allows for the mitigation of wastewater by biological methods. This is accomplished by using bio-filters that are compatible with the ecological conditions of the aquaculture site.

• Increased financial rewards from trading commercially generated by-products: Increased profits through diversification. The farm can obtain additional products that surpass the costs of starting and maintaining an IMTA farm by utilizing the extractive potential of co-cultivated lower trophic level species. In integrated aquaculture, the excess nutrients are used as a resource to support bio-filters.

• Enhancing the local economy: Promoting economic expansion by creating jobs both directly and indirectly, as well as by processing and distributing goods.

• Inherent risk mitigation strategy: Product diversification can provide financial stability and lessen economic susceptibilities to price swings, crop losses from disease, or unfavorable weather.

• Disease management: Because of their antibacterial qualities against fish-pathogenic microorganisms, some seaweed species can help prevent or lessen fish infections.

• Increased revenue through premium pricing; the ability to set IMTA products apart through eco-labeling programs or obtaining organic certification.

### References

1. Barrington, K., Chopin, T., & Robinson, S. (2009). Inte-

grated multi-trophic aquaculture (IMTA) in marine temperate waters. Integrated mariculture: a global review. FAO Fisheries and Aquaculture Technical Paper, 529, 7-46.

2. Biswas, G., Kumar, P., Kailasam, M., Ghoshal, T. K., Bera, A., & Vijayan, K. K. (2019). Application of Integrated Multi Trophic Aquaculture (IMTA) concept in brackishwater ecosystem: the first exploratory trial in the Sundarban, India. Journal of Coastal Research, 86(SI), 49-55.

3. Buschmann, A. H., Mora, O. A., Gómez, P., Böttger, M., Buitano, S., Retamales, C., & Gutierrez, A. (1994). Gracilaria chilensis outdoor tank cultivation in Chile: use of land-based salmon culture effluents. Aquacultural Engineering, 13(4), 283-300.

4. Chopin T., Buschmann A.H., Halling C., Troell M., Kautsky N., Neori A., Kraemer G.P., Zertuche-Gonzalez J.A., Yarish C. & Neefus C. (2001) Integrating seaweeds into marine aquaculture systems: a key towards sustainability. Journal of Phycology 37, 975–986.

5. Harlin, M. M., Thorne-Miller, B., & Thursby, G. B. (1979). Ammonium Uptake by Gracilaria Sp.(Florideophyceae) and Ulva Lactuca (Chlorphyceae) in Closed System Fish Culture. University of Rhode Island.

6. Lamprianidou, F., Telfer, T., & Ross, L. G. (2015). A model for optimization of the productivity and bioremediation efficiency of marine integrated multitrophic aquaculture. Estuarine, Coastal and Shelf Science, 164, 253-264.

7. McDonald, M. E. (1987). Interactions between a phytoplanktivorous fish, Oreochromis aureus, and two unialgal forage populations. Environmental biology of fishes, 18(3), 229-234.

8. Nelson, E. J., MacDonald, B. A., & Robinson, S. M. C. (2012). The absorption efficiency of the suspension-feeding sea cucumber, Cucumaria frondosa, and its potential as an extractive integrated multi-trophic aquaculture (IMTA) species. Aquaculture, 370, 19-25.

9. Neori, A. (1991). Use of seaweed biofilters to increase mariculture intensification and upgrade its effluents. Fisheries and Fishbreeding in Israel: Review of Fisheries in Israel, 24, 171-179.

10. Pinak B, Iqbal G, Bambhaniya I (2023) Integrated multi-trophic aquaculture system (IMTA), chapter-8. AkiNik Publications, Traditional and Recent Aquaculture Practices. India, 107–125.

11. Ryther, J. H., Goldman, J. C., Gifford, C. E., Huguenin, J. E., Wing, A. S., Clarner, J. P., ... & Lapointe, B. E. (1975). Physical models of integrated waste recycling-marine polyculture systems. Aquaculture, 5(2), 163-177.

12. Sanz-Lazaro, C., & Sanchez-Jerez, P. (2020). Regional integrated multi-trophic aquaculture (RIMTA): spatially separated, ecologically linked. Journal of Environmental Management, 271, 110921.

13. Sasikumar, G., & Viji, C. S. (2015). Integrated multi-trophic aquaculture systems (imta).

14. Shpigel, M., Neori, A., Popper, D. M., & Gordin, H. (1993). A proposed model for "environmentally clean" land-based culture of fish, bivalves and seaweeds. Aquaculture, 117(1-2), 115-128.

15. Tang, Y., Tang, Y., Chen, R., Chen, L., Zhou, D., Xue, J., & Zhang, Y. (2024). Assessing the potential of mariculture to provide ecosystem services based on cultured species, modes and regions. Ocean & Coastal Management, 256, 107294.

16. Troell, M., Halling, C., Neori, A., Chopin, T., Buschmann, A. H., Kautsky, N., & Yarish, C. (2003). Integrated mariculture: asking the right questions. Aquaculture, 226(1-4), 69-90.

17. Troell, M., Joyce, A., Chopin, T., Neori, A., Buschmann, A. H., & Fang, J. G. (2009). Ecological engineering in aquaculture—potential for integrated multi-trophic aquaculture (IMTA) in marine offshore systems. Aquaculture, 297(1-4), 1-9.

18. Troell, M., Rönnbäck, P., Halling, C., Kautsky, N., & Buschmann, A. (1999). Ecological engineering in aquaculture: use of seaweeds for removing nutrients from intensive mariculture. Journal of applied Phycology, 11(1), 89-97.

19. Zhang, M. Q., Yang, J. L., Lai, X. X., Li, W., Zhan, M. J., Zhang, C. P., ... & Shu, H. (2022). Effects of integrated multi-trophic aquaculture on microbial communities, antibiotic resistance genes, and cultured species: A case study of four mariculture systems. Aquaculture, 557, 738322.