# A review of fresh water integrated multi-trophic aquaculture (FIMTA): Catching up on the dream of a blue revolution in India

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Integrated multi-trophic aquaculture (IMTA) is a flexible concept, on which many variations can be developed and should not be viewed as confined to open-water, marine systems. Freshwater Integrated Multi-Trophic Aquaculture (FIMTA) is perhaps better known as "aquaponics." FIMTA applies the same principles as those used in marine IMTA but takes place in a freshwater setting. It is not only important for branding purposes, but can also increase the sustainability of the industry by reducing water usage and waste production, increase product diversification, and improve the societal acceptance of the industry. In particular, using plants to reduce phosphorus (and other nutrient) levels in effluents can help farmers meet water quality guidelines and prevent eutrophication in the environment.

Aquaponics is a form of FIMTA that combines aquatic animal and plant culture, through a microbial link and in a symbiotic relationship. It uses microbes to convert organic wastes produced by the fish into inorganic nutrients that are then consumed by plants, which also absorb inorganic nutrients that are available directly. This technology can be adapted to many fish- and plant species, in a range of growing conditions, and with a variety of techniques, including floating rafts and media filled beds.

Over the last two and a half years, a comprehensive field and laboratory feasibility study was conducted to investigate the potential for developing land-based freshwater IMTA (or FIMTA) systems for Atlantic salmon hatcheries operated in New Brunswick, Canada, by our industry partner, Cooke Aquaculture Inc. Both flow-through and recirculating facilities were assessed to design the most appropriate systems based on water quality, nutrient loading, flow- and discharge characteristics. Also important are nutrient concentrations and bioavailability, temperature, light, space availability, plant specific growth, absorption requirements, and economic viability and markets. The analyses indicate that recirculating hatcheries are more valuable candidates for FIMTA systems than conventional flow-through hatcheries.

## Concept of integrated multi-trophic aquaculture

In many monoculture farming systems the fed-aquaculture species and the organic/ inorganic extractive aquaculture species (bivalves, herbivorous fishes and aquatic plants) are independently farmed in different geographical locations, resulting in pronounced shift in the environmental processes. Integrated multi-trophic aquaculture involves cultivating fed species with extractive species that utilise the inorganic and organic wastes from aquaculture for their growth. According to Barrington (2009), IMTA is the practice which combines, in the appropriate proportions, the cultivation of fed aquaculture species (e.g. finfish/shrimp) with organic extractive aquaculture species (e.g. shellfish/herbivorous fish) and inorganic extractive aquaculture species (e.g. seaweed) to create balanced systems for environmental sustainability (bio-mitigation) economic stability (product diversification and risk reduction) and social acceptability (better management practices).This farming method is different from finfish "polyculture", where the fishes share the same biological and chemical processes which could potentially lead to shifts in ecosystems. Multi-trophic refers to the combination of species from different trophic levels in the same system. The multi-trophic sub-systems are integrated in IMTA that refers to the more intensive cultivation of the different species in proximity of each other, linked by nutrient and energy transfer through water.

## Selection of species

Environmental sustainability is the major consideration in FIMTA, therefore the criteria guiding species selection is the imitation of natural ecosystem. Fed organisms, such as carnivorous fish and shrimp are nourished by feed, comprising of pellets or trash fish. Extractive organisms, extract their nourishment from the environment. The two economically important cultured groups that fall into this category are bivalves and plants. Combinations of co-cultured species will have to be carefully selected according to a number of conditions and criteria:

- **Complementary roles with other species in the system:** Use species that will complement each other on different trophic levels. For example, species must be able to feed on the other species' waste in order for the newly integrated species to improve the quality of the water and grow efficiently. Not all species can be grown together efficiently.

- **Adaptability in relation to the habitat:** Native species that are well within their normal geographic range and for which technology is available can be used. This will help to prevent the risk of invasive species causing harm to the local environment, and potentially harming other economic activities. Native species have also evolved to be well adapted to the local conditions.

- **Culture technologies and site environmental conditions:** Particulate organic matter and dissolved inorganic nutrients should be both considered, as well as the size range of particles, when selecting a farm site.

- **Ability to provide both efficient and continuous bio-mitigation:** Use species that are capable of growing to a significant biomass. This feature is important if the organisms are to act as a bio-filter that captures many of the excess nutrients and that can be harvested from the water. The other alternative is to have a species with a very high value, in which case lesser volumes can be grown. However, with the latter, the bio-mitigating role is reduced.

- **Market demand for the species and pricing as raw material or for their derived products:** Use species that have an established or perceived market value. Farmers must be able to sell the alternative species in order to increase their economic input. Therefore, they should establish buyers in markets before investing too heavily.

- **Commercialisation potential:** Use species, for which regulators and policy makers will facilitate the exploration of new markets, not impose new regulatory impediments to commercialisation.

- Contribution to improved environmental performance.

- Compatibility with a variety of social and political issues.

## Benefits

In an experimental system in China extractive organisms - plants and shellfish - remove the excess nutrients from the water that is circulated between the fish rearing compartment of the pond and the water treatment unit. In Hungary the effluent of an intensive African catfish production system is efficiently treated on a constructed wetland where filter feeding fish species and plants are used for nutrient removal. Results of the experiments are being transferred to the practice.

- **Effluent bio-mitigation:** Mitigation of effluents through the use of bio-filters which are suited to the ecological niche of the aquaculture site. This can solve a number of the environmental challenges posed by monoculture aquaculture.

- **Increased profits through diversification:** Increased overall economic value of an operation from the commercial by-products that are cultivated and sold. The complexity of any bio-filtration comes at a significant financial cost. To make environmentally friendly aquaculture competitive, it is necessary to raise its revenues. By exploiting the extractive capacities of co-cultured lower trophic level taxa, the farm can obtain added products that can outweigh the added costs involved in constructing and operating an IMTA farm. The waste nutrients are considered in integrated aquaculture not a burden but a resource, for the auxiliary culture of bio-filters.

- **Improving local economy:** Economic growth through employment (both direct and indirect) and product processing and distribution.

- **Form of 'natural' crop insurance:** Product diversification may offer financial protection and decrease economic risks when price fluctuations occur, or if one of the crops is lost to disease or inclement weather.

- **Disease control:** Prevention or reduction of disease among farmed fish can be provided by certain seaweeds due to their antibacterial activity against fish pathogenic bacteria.

- **Increased profits through obtaining premium prices:** Potential for differentiation of the IMTA products through eco-labelling or organic certification programmes.

## Challenges

Integrated aquaculture is not without challenges. These include:

- **Higher investment:** Integrated farming in open sea requires a higher level of technological and engineering sophistication and up-front investment.

- **Difficulty in coordination:** If practised by means of different operators (e.g. independent fish farmers and mussel farmers) working in concert, it would require close collaboration and coordination of management and production activities.

- I**ncrease requirement of farming area:** While aquaculture has the potential to reduce pressure on fish resources and IMTA has specific potential benefits for the enterprises and the environment, fish farming competes with other users for the scarce coastal and marine habitats. Stakeholder conflicts are common and range from concerns about pollution and impacts on wild fish populations to site allocation and local priorities. The challenges for expanding IMTA practice are therefore significant although it can offer a mitigation opportunity to those areas where mariculture has a poor public image and competes for space with other activities.

- **Difficulty in implementation without open water leasing policies:** Few countries have national aquaculture plans or well developed integrated management of coastal zones. This means that decisions on site selection, licensing and regulation are often ad hoc and highly subject to political pressures and local priorities. Moreover, as congestion in the coastal zone increases, many mariculture sites are threatened by urban and industrial pollution and accidental damage.

## Prospects

There is tremendous opportunity to use marine macroalgae as bio-filters, process and produce products of commercial value. Globally, most open-water seaweed monoculture has taken place in Asia, South America, South Africa and East Africa. In 2013, 26.9 million tonnes (wet weight) of aquatic plants from aquaculture was harvested worldwide, while capture production was only 1.3 million tonnes, with China and Indonesia accounting for the major share in production. Instead of monoculture, a fraction of the seaweed aquaculture practice can be integrated with fed-aquaculture as bio-filters. This approach may generate a heightened commercial interest once high value seaweeds species can be cultured as biofilters that produce novel human food products. Aquatic plants and algae may offer similar opportunities in freshwater environments.

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# Pre-pupae (larvae) of black soldier fly-a potential alternate protein source for aquaculture feeds

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*Black soldier fly, Hermetia illucens, National Arboretum, Washington, D.C.*

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Feed represents a large proportion of expenditure in fish farming and current farming practices mean that the main limiting factor in terms of feed is the use of fish meal and fish oil (Tacon and Metian, 2008). Fish meal is a major source of protein used in the formulation of feed for different fish species to increase feed efficiency and growth, as it helps to enhance feed palatability; nutrient uptake, digestion and absorption. The balanced amino acid composition of fish meal complements other animal and vegetable proteins to provide synergistic effects that promote faster growth (Mile and Chapman, 2006). Fishmeal has low fibre content and is also a valuable source of vitamins B1, B2, B6 and B12, in addition to calcium, phosphorous, magnesium, potassium, trace elements, attractants and fatty acids (Sheen et al., 2014; Dawood et al., 2015).

Approximately 20 million tonnes of the total marine catches go into the production of fish meal (Natale et al., 2013), equivalent to 36% of the total wild capture fishery production. However, total output from capture fisheries have not