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A look at integrated multi-trophic aquaculture

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Ancient, adaptable concept focuses on ecological integration

While the principles on which all IMTA systems are based are the same, hydrodynamic, weather and historical conditions affect the final form of facilities like this IMTA farm of Cooke Aquaculture in eastern Canada.

Integrated multi-trophic aquaculture (IMTA) is the farming, in proximity, of species from different trophic levels and with complementary ecosystem functions in a way that allows one species' uneaten feed and wastes, nutrients and by-products to be recaptured and converted into fertilizer, feed and energy for the other crops, and to take advantage of synergistic interactions among species while bio-mitigation takes place.

Farmers combine the cultivation of fed species such as finfish or shrimp with extractive species, such as seaweeds and aquatic plants that recapture inorganic dis-solved nutrients, and shellfish and other invertebrates that recapture organic particulate nutrients for their growth.

The aim is to ecologically engineer aquaculture systems for increased environmental sustainability; economic stability through improved output, lower costs, product diversification, risk reduction and job creation; and societal acceptability.

Origins of IMTA

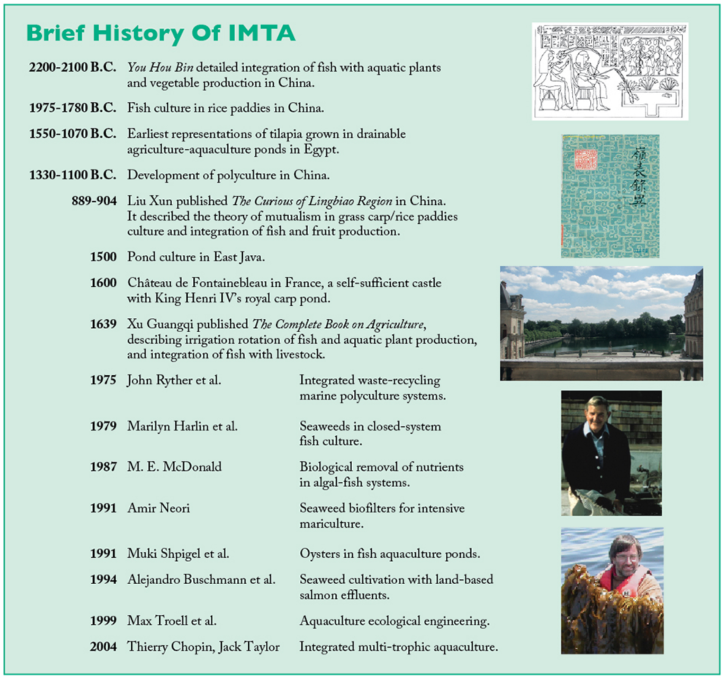
IMTA can be traced back to the origins of aquaculture. In 2200-2100 B.C., the document *You Hou Bin* detailed the integration of fish with aquatic plants and vegetable production in China. There is evidence of tilapia grown in integrated agriculture-aquaculture drainable ponds on bas-reliefs in tombs built during the era of the New Kingdom in Egypt, which occurred about 1550-1070 B.C.

During the French Renaissance, royal IMTA was practiced at the Château de Fontainebleau, as attested by the construction of the Etang aux Carpes (Carp Pond), which still functions to this day. French King Henri IV had given instructions that the estate should be self-sufficient and could not depend on provisions, which had the chance of being looted several times during the 65-km trip from Paris.

In 1639, *Nong Zheng Quan Shu (The Complete Book on Agriculture)* by Xu Guangqi was published posthumously. He had been collaborating with Jesuit missionaries. His comprehensive treatise covered many topics, including irrigation and the rotation of fish and aquatic plant production. Also described were the integration of fish with livestock and the effects of manure on pond production, as well as the integrated production of mulberry trees, rice paddies and fish ponds.

In the 1970s, John Ryther reignited interest in IMTA and can be considered the grandfather of modern IMTA for his seminal work on what he called "integrated waste-recycling marine polyculture systems," first at Woods Hole Oceanographic Institution in Massachusetts, USA, and then at Harbor Branch Oceanographic Institute in Florida, USA.

It was followed by three productive decades on what has been variously called polyculture, integrated mariculture or aquaculture, ecologically engineered aquaculture and ecological aquaculture. Understanding the need to harmonize all these names, the author and Jack Taylor combined integrated aquaculture and multi-trophic aquaculture into the term integrated multi-trophic aquaculture in 2004.



IMTA defined

IMTA is based on a very simple principle. "The solution to nutrification is not dilution, but extraction and conversion through diversification," which is another way of expressing the principle of conservation of mass, as formulated by Antoine-Laurent de Lavoisier in 1789. "Nothing is created, nothing is lost, everything is transformed," he said.

What is important is that the appropriate organisms to be co-cultured are chosen at multiple trophic levels based on their complementary functions in the ecosystem, as well as their economic value or potential. Integration should be understood as cultivation in proximity, not considering absolute distances but connectivity in terms of eco-systemic functionalities.

Some remain perplexed at the choice of the IMTA acronym when the term "poly-culture" already exists. Cultivating three species of fish is indeed polyculture, but from an ecosystem approach, this is typically the cultivation of species that all share the same general biological, physiological, nutritional and chemical processes. No attempt is made at using species that counterbalance each others' processes, which could potentially lead to significant shifts in the ecosystem.

Consequently, integrated multi-trophic aquaculture is the best way to describe the principles at work in this evolution of aquaculture practices.

Central theme, many variations

The IMTA concept is extremely flexible. It is the central/overarching theme on which many variations can be developed. IMTA can be applied to open-water or land-based systems (sometimes called aquaponics), marine or freshwater systems, and temperate or tropical systems.

In the minds of those who created the acronym IMTA, it was never conceived as only the cultivation of salmon, kelps, blue mussels and other invertebrates in temperate waters and within a few hundred meters. This is only one of the variations, and the IMTA concept can be extended to very large ecosystems.

The scope of IMTA can cover a whole range of operations, from integrated agriculture aquaculture and integrated fisheries aquaculture to partitioned aquaculture, integrated periurban aquaculture and integrated food and renewable energy parks. All should be considered variations on the central IMTA theme.

There is no ultimate IMTA system to feed the world. Different climatic, environmental, biological, physical, chemical, economic, historical, societal, political and governance conditions, prevailing in the parts of the world where they operate, can lead to different choices in the design of the best-suited IMTA systems, but all of them are based on the same principles of the IMTA concept.

IMTA farm of Kyuquot Seafoods Ltd. on Vancouver Island in western Canada.

Fed, extractive balance needed

Total agriculture production is around 6.3 billion tons per year, divided into 82 percent plant production and 18 percent animal production. Aquaculture, totaling 78.9 million tons per year, is divided into almost the reverse proportions, with 76 percent animal production and 24 percent seaweeds and aquatic plant production.

Mariculture appears somewhat more equilibrated, with a total annual production of about 37.1 million tons, split between 19 million tons (51 percent) of seaweed production and 18.1 million tons (49 percent) of animal production. However, a weight ratio approach would still need to be applied to the different species to determine what culture proportions would result in a balance of the global mariculture nutrient load. Moreover, 99 percent of seaweed aquaculture is presently concentrated in seven Asian countries: China, Indonesia, the Philippines, South Korea, North Korea, Japan and Malaysia.

Consequently, if aquaculture is to make a major contribution to the efficient and responsible food production systems of the future, far more production of inorganic extractive seaweeds and aquatic plants, and organic extractive animals, must be developed in a more evenly distributed manner throughout the world.

We urgently need to think of applying aquanomic principles to the management of our aquatic resources, as we have done on land with the development of agronomic principles improved over centuries. We, unfortunately, do not have the luxury of time with an ever-growing human population.

Humans will soon not be able to continue thinking of mostly land-based agricultural solutions for securing their food, as well as provisioning many other derived products, but will have to turn increasingly to responsible aquanomy to manage their "aquatic fields." The "Blue Revolution" needs to become greener, and that is why we need to talk about the "Turquoise Revolution" to describe the evolution in aquaculture practices.

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