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IMTA KEY CONCEPT FOR DEVELOPING A STRATEGY TO INCREASE AQUACULTURE PRODUCTION AND IMPROVE ENVIRONMENTAL SUSTAINABILITY

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Abstract

This paper is a comprehensive study of the strategic approach, in the context of global population growth, to create more food using current natural resources. Integrated multi-trophic aquaculture (IMTA) can provide aquaculture products in much larger quantities using the same resources involved. Harnessing all the waste in the waters for this purpose brings multiple environmental and economic benefits. In the context of the circular economy, IMTA principles aim to significantly reduce waste and degrade the environment, but without restricting economic and social progress. In Romania, polyculture fish farming is practised to exploit all aquatic resources in fish farms. Each fish species is selected so that it can be nutritionally supported with natural feed from the environment, and various types of feed can be used to increase production. The results of the study can be used to improve the aquaculture development strategy, in the environmental sustainability context.

Key words: *aquaculture products, multi-trophic aquaculture, resource valorisation, sustainability, trophic level.*

INTRODUCTION

Integrated multi-trophic aquaculture (IMTA) is a similar practice to classic polyculture, in which the nutritional requirement is higher for all trophic levels and the use of feed is at full capacity. Aquaponics (the combination of aquaculture and hydroponics), fractional aquaculture, aquaculture and integrated systems, integrated peri-urban aquaculture systems and integrated fisheries systems are all variants of the key IMTA totalitarian concept. In this type of aquaculture there is an improvement in the efficiency of the growth of several aquatic species and a reduction of waste in the environment. Faecal matter from the upper trophic level is used by the lower trophic levels to increase the resource use efficiency of the rearing tanks. Lower trophic species can provide additional income while bringing multiple benefits to current practices in the sector. Making the most of the nutrient sources in the environment contributes to increasing its sustainability and creating new concerns in the field. The first published account of aquaculture dates back to 475 B.C. (Borgese, 1980). In 1970, John Ryther, considered the grandfather of integrated multi-trophic aquaculture (Chopin, 2013), together with his collaborators, developed modern mariculture, which is still practiced today in an integrated and intensive way. They demonstrated, both theoretically and experimentally, the integrated use of extractive organisms crustaceans, microalgae and seaweed in the treatment of domestic effluents, descriptively and with quantitative results. A source of used it was a domestic which was mixed with seawater, being considered as the nutrient source for phytoplankton, which in turn became food for clams and oysters (Rabanal, 1988). Nutrient wastes dissolved in the final effluent were filtered through biofilters from seaweeds (mainly Gracilaria and Ulva).

Globally, integrated multi-trophic aquaculture is the focus of extensive research to improve current practices in the industry and help develop a plan to increase production with a minimal environmental footprint. Increasing profitability in the context of this type of aquaculture implies bringing together more knowledge and setting the most environmentally friendly trajectory possible. For farmers involved in aquaculture this phenomenon brings multiple benefits with the valorisation of all resources and by-products resulting from the main fish farming process. Lower trophic chains can in turn use the excretion products from the main activity carried out, while boosting profits and obtaining more aquaculture products.

The main drawbacks of current fish farming systems highlight the use of large amounts of supplementary feed and the use of a large volume of water resulting in a large amount of externalised waste. In order to eliminate or reduce these disadvantages, a multilateral approach to the problems presented is needed, with the creation of new vectors capable of taking economic activity to another level. These vectors are under the scrutiny of many global organisations working to preserve and enhance environmental sustainability.

With alarming global population growth, the demands of providing the food needed to sustain this expansion are increasingly difficult to meet. With the global population growth, there is practically a shrinking of agricultural land and thus a reduction in the quantity of agri-food products. In order to compensate for this phenomenon, the active involvement of all resources to stabilise the balance is essential.

The strategic objectives aim to achieve more food per unit of decreasing area.

Integrated multi-trophic aquaculture emphasises the valuable qualities of algae by the way they purify water and thus ensure the health of aquatic ecosystems. Their ability to extract valuable components from the debris released into the pond by the first trophic chain is an important characteristic to be studied in detail.

In order to eradicate as much as possible the problems faced by European aquaculture such as: causing ecological damage and co-dependence on commercial feed, but also ensuring economic stability IMTA is an advantageous solution (Klinger & Naylor, 2012; Chopin et al., 2013; Granada et al., 2015; Hughes & Black, 2016).

MATERIALS AND METHODS

This study is a synthesis of the most comprehensive articles, which focus on the implementation of the key concept, of integrated multi-trophic aquaculture and its strengths/weaknesses. How the implementation of the IMTA key concept improves fish production and stimulates farmers in its application are some of the preliminary advantages. The development of a schematic analysis, of the main advantages following this concept, highlights the strengths of developing such a technology to increase productivity and reduce the environmental footprint.

RESULTS AND DISCUSSIONS

The most common aquaculture practice at national level is polyculture fish farming, but in other countries with intense concerns about the aquaculture sector, new approaches to this concept are being sought and the possibilities of combining different categories of life to create a symbiosis between them are being broadened. The establishment of such relationships is in some cases more difficult to control due to the particularities of each species involved. As the IMTA concept continues to change, it is important that all sectors involved in this industry are aware of the consequences of the changes involved so that they can adapt quickly and in an organised way. In order for research to move from 'pilot' to 'scale-up', some current regulations and policies may need to be changed, otherwise they will be seen as obstacles by industry partners, who will see no incentive to develop IMTA. This concept promotes economic and environmental sustainability through product transformation by-products and feed not consumed by organisms fed on intensive crops, thereby reducing eutrophication and increasing economic diversification (Bardach et al., 1972).

Properly managed multi-trophic aquaculture accelerates productivity growth without harmful side effects (Table 1).

Improving productivity and reducing environmental impact according to (Wang el al., 2012), the production of one tonne of salmon results in a release of 50 kg of nitrogen into the environment, which could support the farming of 10 tons of algae or 5 tons of mussels over the entire fish production cycle (Holdt & Edwards, 2014). By recirculating nitrogen back into the farming system, a reduction in lipid and protein requirements occurs, thus decreasing the industry's negative impact on the environment while making production more efficient.

Table 1. SWOT analysis for IMTA key concept implementation (original)

SWOT analysis	
<u>Strengths</u> Increased production yield; Lower specific consumption; Use of the same land for additional production; Recovery of waste from the main activity.	<u>Weaknesses</u> Overpopulation of water bodies; Uneven growth of stocked fish material; Excess development of aquatic biomass; Destabilisation of physical-chemical water parameters. Fish escape from cages in open waters
<u>Opportunities</u> Increased production capacity; Increased numbers of living organisms and cultivated plants; Capture a larger sector of the market.	<u>Threats</u> Lack of knowledge about certain phenomena that occur gradually in production; Involvement of additional costs not foreseen in the initial financial analysis; Lack of knowledgeable staff.

The two types of wastes of interest are dissolved nutrients and organic materials such as: faecal matter and forage (in any form) not fully consumed (Sanderson et al., 2008). Trophic nutrient transfer, considered an ecological benefit, must occur in the proximity of farms; hence the potential for bioremediation in this perimeter is limited for algae and all sub-consumers of the intermediate chain (Broch et al., 2013; Cranford et al., 2013). Integrated Multi-Trophic Aquaculture (IMTA) is one of the modern aquaculture practices using offshore fish cages that are similar around the world (Figure 1). The design and degree of automation can change depending on the production, with the exception of floating closed containment schemes (Partridge et al., 2006; Fredriksson et al., 2008), most marine fish cages are operated as continuous flow rearing systems with floating nets.

Over time, the advent of "organic aquaculture" licences in countries such as Norway and Denmark has sparked a growing interest in obtaining such accreditations. At the same time, the increasing profitability of the sector, with decreasing environmental emissions, is stimulating individual operators to take new steps to align themselves with this strategy. In this way, extractive aquaculture produces a good amount of biomass, while providing the existing aquatic ecosystem with biomitical services for the surrounding ecosystem.

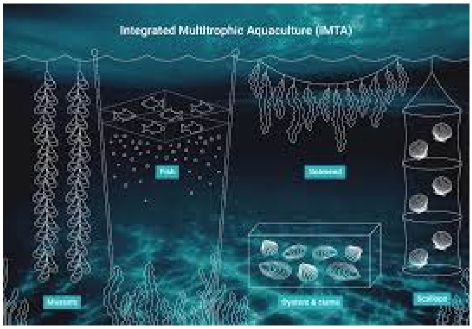

Figure 1. Schematic view of IMTA suitable marine species (Source: Magazine, 2022)

Bioremediation through IMTA in countries such as China to minimize the impact of nutrient losses from land to coastal waters has been remedied by large-scale cultivation of various species of seaweed, which subsequently succeeded in reducing nitrogen levels in the environment, successfully controlled phytoplankton spawning, and limited occurrence of toxic algal species (Xiao et al., 2017). Through multi-trophic aquaculture, a quantity of uneaten feed and waste, nutrients and by-products, considered "lost" from the feed, are recovered and transformed into feed that is easy to reintroduce into the production cycle and healthy, healthy and commercially valuable seafood through the removal of a partial amount of nutrients and CO , and the subsequent supply of O_2-oxygen. IMTA compliance can provide the producer with the economic security they need, even when production conditions are unfavourable (Whitmarsh et al., 2006; Ridler et al., 2007). Asia, supports more than two-thirds of the world's aquaculture production, IMTA was practiced here through trial and error, and experimentation many centuries ago (Sifa, 1987).

Interestingly, the civilisations that have made the most progress in developing integrated aquaculture systems regard waste as a valuable resource and have long since integrated the nutrients resulting from the first feeding stage. (Ling, 1977).

Efficient combinations of plants and aquatic organisms

Much attention has recently been focused on the specific interconnection between aquatic animals and algae in the water source. The most common combinations are those in which fish are the main link in the food chain, with other types of consumers such as crayfish, clams, in the case of seawater use shrimps and other crustacean species being introduced into the system in varying proportions. The combined use of these species makes it easier to obtain a greater quantity of product per unit area and to reduce losses. Integrated multi-trophic aquaculture, mainly based on the integrated selective culture of several fed aquatic species, such as fish, inorganic extractive species, (marine algae), and organic extractive species, promises to contribute to the sustainability of aquaculture (Chopin et al., 2002). The IMTA key concept is highly flexible. It can be applied in open water or terrestrial systems, in marine or freshwater systems (sometimes referred to as 'aquaponics') and in temperate or tropical systems (Figure 2).

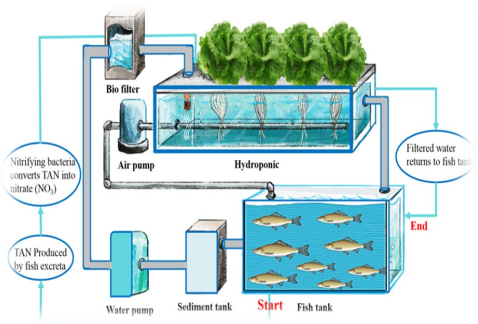

Figure 2. Aquaponics system diagram (after Taha et al., 2022)

Significantly, suitable organisms are picked at different trophic levels based on their complementarity, their complementary roles in the biosystem and their ecological value or economic potential. In fact, IMTA does nothing more than recreate a simplified ecosystem that is in harmony with its environment, instead of introducing a single type of active biomass that is thought to be easily cultivated in isolation from all other aquatic organisms.

Integration as a concept should be understood as growing in proximity, not taking into account absolute distances, but rather connectivity in terms of ecosystem functionalities in the environment (Chopin et al., 2013). The viability of seaweed production is studied in both terrestrial and freshwater cultures, confirming that the nutrients delivered by supplementally fed aquatic life species are suitable for the growth of economically important seaweeds (Troell et al., 1999). The growth and rearing performance of seaweed is largely influenced by the appropriate selection of fish species, the design of the farm in which the experiment is conducted, feeding practices and other activity-specific parameters. The current economic situation and the factors related to it also differ from place to place. Therefore, the development of each farm applying the IMTA concept should aim to optimise for each individual aquaculture site. Organic effluents in whatever form they occur, resulting in concentrated forms from aquaculture farms can induced a series of negative effects with environmental impacts at the local level and can cause oxygen disturbance, eutrophication, changes in the biodiversity ecosystems and pollution of the water sources (Troell et al., 2003).

Population forms for growing fisheries taking into account the IMTA concept and introducing new consumer categories

Different fish farming technologies are used in fish farming depending on the type of fish farm and the purpose of the farmer. Countries such as Japan, China, South Korea, Thailand, Vietnam, Bangladesh, Indonesia cultivate aquatic species in both marine, wild and freshwater environments. They produce fish, shellfish and algae together in: ponds, lagoons, bays, etc.

Fish farming technologies are conditioned by: length of the growing season, management of existing fish stocks, use of fertilisers - fertilisation, supplementary feeding and production planning.

Many types of aquatic ponds can be successfully used for this method of fish farming: ponds, natural or artificial lakes, various water accumulations, canals or even rivers. As far as aquaculture production is concerned, it has been intensified by introducing more species into the system, which can cause a number of negative effects, such as degradation of water and soil quality in aquaculture ponds, stress and weak fish performance, a reduced profitability margin and overall environmental decline. In view of this, IMTA has proven the potential for greater crop diversity than a conventional commercial crop by introducing different consumers, such as molluscs and plants that can grow in water, such as water spinach, into the same pond (Kibria & Haque, 2018). Systems include agricultural/agricultural practices such as rice-fish and rice-crab, including the use of rice and crab to restore unproductive land to production in Inner Mongolia utilizing a rice variety that tolerates salt rates of up to 6 ppm. The diversification of production has significantly increased pond productivity while keeping water purity parameters at equilibrium levels in line with IMTA guidelines. This implies that IMTA could be advocated as effective for potential farmers to support food security for the poor. At S.C.D.P Nucet, the sturgeon *Polyodon spathula* was acclimatized and research was conducted on its feeding spectrum. (Costache et al., 2017). Therefore it can be introduced in ponds together with other planktonic fishes to exploit all the nutritive substrates. It can be introduced in ponds of 1 ha such as: 1000/sp carp, silver carp 500/sp, Polyodon 150/sp, raptors 200/sp. (Costache et al., 2020). The main food type of this fish is zooplankton. Therefore, it can be introduced into ponds together with other planktophagous fishes in order to exploit all the nutritive substrates.

Expanding production by growing different types of plants and molluscs

Freshwater snails eat organic detritus, seaweed and zooplankton, which in turn provide food for many fish species, birds and people. Snails are bioindicators and play a crucial role in the cleaning of water bodies, as they are saprophytes organism. Organic waste from unconsumed fish food in turn accumulates at the bottom of ponds and is used by snails as a food resource. Crustaceans take up intermediate trophic levels and sometimes play a dual function, both by filtering organics from the bottom and by generating ammonia. Food waste can also deliver additional nutrients; sometimes through direct ingestion, sometimes through breakdown as individual nutrients. In addition projects, nutrient residues are also collected and recycled into feed for captive fish. This can be done by processing cultured algae as feed. Water spinach is a very popular vegetable in Bangladesh for human food - all edible parts, except the submerged down parts, of the water spinach plant are edible. Water spinach thrives well in freshwater ponds throughout the whole year in tropical areas of the planet and needs sufficient nutrients, especially nitrogen. As observations from ponds where the IMTA concept was applied show, the growth of water spinach roots was of medium size; they did not reach the bottom of the water body but absorbed nutrients from the surrounding environment under immersed circumstances. This also showed that water spinach displayed a bio-mitigation effect and maintained nitrogenous residue concentrations in appropriate limits.

There is great uncertainty about climate change, the stability of aquatic ecosystems, fluctuating international markets and the preferences of consumers and other stakeholders. However, nutrient and by-product recirculation in aquaculture will certainly play a valuable role in increasing specific yields of global production. One of the principal benefits of filter feeding bodies such as Porifera is that their primary source of power is provided by super-efficient purification of organic particles ranging in size from 0.1 to 50 μm, such as suspended organic particles, eukaryotes and heterotrophs, phytoplankton and so on, such that their simple increase results in bioremediation of the surrounding environment. As a result, they are viewed as a possible way to reduce eutrophication and bacterial stock (Joseba et al., 2023). Water quality parameters are very important for aquaculture and depend on management issues such as stocking density, stocking material cultured organisms and supplements applied etc.

CONCLUSIONS

Hunger and unbalanced diets are still some of the most bitter problems facing humanity. In addition, there are growing concerns about the long-term viability of so many food production regimes, even fisheries and aquaculture, to meet future growing global supply demands. In this respect, implementing new, environmentally friendly practices that are friendly to institutions with such concerns are among the most readily available solutions of the moment. IMTA is essentially about matching needs with trade-offs to achieve a favourable long-term outcome of the food crisis.

In addition to the many advantages of the IMTA key concept, there are also some disadvantages of this practice. The costs of implementing such a system are often relatively high in the beginning, and the lack of knowledge on the subject is a real impediment. In addition to the two disadvantages mentioned above, in the case of combining several activities, there is the likelihood of overpopulation of the water body and its saturation.

Poor management of feed in the aquatic environment can also lead to excess formation of secretion products, which are reflected in an increase of organic matter in the water and hydrogen sulphide levels above normal limits. Solving these problems implies costs, which have ramifications for both the consumer market and aquaculture producers.

The circular economy can allow the aquaculture sector to grow and contribute by improving food products to increase as much as possible the timeframe in which resource depletion does not occur.

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