Coastal Open-Water Modelling Integrated Multi-Trophic Aquaculture (IMTA) based on Blue Economy

Abdul Ghofur Ragil Insani[1], R. O. Saut Gurning[1], Badrus Zaman[1], Semin[1]
[1]*Department of Marine Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, 6011, Indonesia*

Keywords: Blue Economy, Coastal Open-Water Modelling, Integrated Multi-Trophic Aquaculture (IMTA).

Abstract: Integrated Multi-Trophic Aquaculture IMTA is an environmentally friendly solution and sustainability of aquaculture or aquaculture. IMTA is one form of marine cultivation by utilizing the provision of ecosystem services by low trophic organisms (such as shellfish and seaweed) that are adjusted as mitigation of waste from high trophic level organisms (such as fish). The blue economy is closely related to marine and marine-based sectors, such as the fisheries, transportation and tourism sectors. The survival of marine biota as food ingredients and livelihoods for people around the sea is a blue economic focus to reduce poverty and hunger. Coastal Open-Water modelling of IMTA in Indonesia is very appropriate to be carried out in coastal or coral areas because the area has been damaged due to aquaculture or fishing activities that are not environmentally friendly and environmentally friendly. So that IMTA can be applied on the Indonesian coast with innovation and creativity in order to improve seaweed cultivation that is efficient, environmentally friendly, utilizing other ecosystems that are mutually beneficial, improving the economic welfare of the community, and availability for a long time in accordance with the concept of blue economy.

1 INTRODUCTION

Integrated Multi-Trophic Aquaculture (IMTA) is one form of marine cultivation by utilizing the provision of ecosystem services by low trophic organisms (such as seashells and seaweed) that are adapted as mitigation of waste from high trophic organisms (such as fish) (Jinguang et al, 2009). IMTA is different from polyculture because polyculture is cultivating more than one species without regard to the use of species in ecosystems, while IMTA focuses on the species' ability to maintain ecosystem balance so that each particular species has different functions such as carnivores, herbivores, detritus, biofiltering and invading particles so ecosystem balance can be maintained properly. IMTA can be used in almost all aquaculture containers both sea and land because the concept of ecosystem balance is applied.

The rate of development of intensive aquaculture often results in a negative impact in the form of water quality degradation. The impact of cultivation activities on the environment must be minimized or even eliminated. Therefore, all aquaculture activities must be environmentally oriented so that aquaculture activities can be sustainable. The most visible impact of marine fish farming in floating net cages (KJA) is the presence of residual food decomposed in the water column which can increase the biochemical oxygen demand, increase dissolved phosphate content and increase dissolved nitrogen content. In general, only about 30% of nutrients derived from feed are utilized by fish, and the rest will be released into the water in the form of feed and feces residue, but this depends on the quality of feed provided and cultivation management applied (Radiarta et al, 2014).

This system can be modified by utilizing various organisms in an ecosystem, the ecosystem used is a natural ecosystem or the original habitat of the organism. IMTA in Indonesia is very appropriate to be implemented in coastal or coral areas because the area has been damaged due to marine cultivation or fisheries activities that are not environmentally friendly and environmentally friendly. Floating net cages in this system cultivate carnivore reef fish species such as grouper, snapper and baronang. Duck grouper and tiger grouper species naturally found in reef waters have a high selling price and grouper fish have a slow growth, therefore, in carrying out their cultivation, it is usually carried out several times, but through IMTA monoculture grouper system can be overcome with the results of seaweed and shells that

Insani, A., Gurning, R., Zaman, B. and Semin, .
Coastal Open-Water Modelling Integrated Multi-Trophic Aquaculture (IMTA) based on Blue Economy.
DOI: 10.5220/0008549000490054
In *Proceedings of the 3rd International Conference on Marine Technology (SENTA 2018)*, pages 49-54
ISBN: 978-989-758-436-7

have fast growth. Nutrients in the form of feces and leftovers will be given in the form of solids and will be directly by sea cucumbers or sea urchins or indirectly through the growth of seaweed, phytoplankton and benthos and then utilized by abalone and sea cucumbers. The remaining results are suspense and phytoplankton are used by shellfish so that all waste can be utilized. Organisms that can be utilized are very diverse depending on the region of the archipelago, for example the reef area includes grouper, red snapper and Napoleon fish, as carnivorous organisms or high-level trophic levels. Every fishery activity provides waste, therefore waste can utilize the surrounding organisms or naturally found in the area such as mussel, sea urchins, sea cucumbers and abalone. Then also the utilization of the type of shellfish as trophic level of low-level eaters or reducing waste, shellfish that are used not only shells that can be consumed but pearl shells that have high economic value. Waste in inorganic form can be used in the form of nutrients by seaweed using the longline method or raft method according to the characteristics.

In this case the IMTA method used is utilize nitrogen sequestering species, like shellfish and seaweeds, to take up excess particulate and dissolved wastes expelled by finfish (or shrimp) in an aquaculture setting. This method attempts to replicate a natural ecosystem where the energy output of one trophic level is transferred to the next, lower level. In doing so, waste previously deposited in the water as lost profit can be captured and transformed into another sellable product.

2 LITERATURE REVIEW

2.1 Integrated Multi-Tropic Aquaculture (IMTA)

IMTA is an environmentally friendly solution and sustainability of aquaculture or aquaculture. IMTA system derived from fish feed. Fish feed given in containers is not all capable of being converted into meat and the rest becomes ammonia and CO_2 from gills as a result of metabolism and feces from the results of residual absorption by the body. The remaining feces or residual food waste can be utilized by residual eaters or detritus such as sea cucumbers, abalone, cyclops, lobsters and sea urchins. Waste in the form of suspense or small POM is used by biofilter animals such as shellfish. Waste in inorganic form or in the form of a solution that is not used by animals is used as nutrition for seaweed to grow and develop. Indirectly the transformation of a compound that cannot be utilized into a compound that is utilized for other organisms.

The superiority of the IMTA system can be known based on the economy, environment and food safety for cultivation organisms and humans. The use of IMTA in China provides economic benefits in Qingdao province for 2 years producing 900 kg with a yield of 70,000 yuan / 1600 m2 or 10,000 US dollars / 1600 m2 so that cultivation with IMTA is very beneficial because the product diversification is very large and has high economic value (Jinguang et al, 2009). The impact of the IMTA in China on the environment indirectly reduces global climate change by reducing 1.37 million MT of carbon and 96,000 MT of Nitrogen in the cultivation of seaweed and shellfish in 2006 (Jinguang et al, 2009). Global food security is able to fulfill 15 million MT of marine products for humans (Jinguang et al, 2009), and the application of IMTA can reduce the possibility of spread of disease and its transmission both caused by bacteria and viruses with shellfish cultivation (Mytilus edelis) against salmon in subtropics (Pietrack et al, 2009).

2.2 Blue Economy

The term blue economy was first introduced in 2010 by Gunter Pauli through his book entitled The Blue Economy: 10 years - 100 innovations - 100 million jobs. The blue economy applies the logic of ecosystems, namely ecosystems always work towards a higher level of efficiency to flow nutrients and energy without waste to meet basic needs for all contributors in a system. Furthermore, the blue economy focuses on innovation and creativity which includes product variations, production system efficiency, and structuring of resource management systems. The blue economy is closely related to marine and marine-based sectors, such as the fisheries, transportation and tourism sectors. The survival of marine biota as food ingredients and livelihoods for people around the sea is a blue economic focus to reduce poverty and hunger.

The Blue Economy is mutually supportive with the Green Economy model. It also encompasses the principle of “poverty eradication”, related to food security and livelihoods, although it has a more specific vision: “improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities, including the principles of a low carbon economy based on resource efficiency and social inclusion, in particular in states where future resources are marine related" (Blue Economy, 2016).

The blue economy then develops and is often associated with the development of coastal areas. The concept of the blue economy is in line with the concept of green economy that is environmentally friendly and focused on developing countries with territorial waters (sea), commonly known as Small Island Development States (SIDS). The blue economy in this case is aimed at overcoming hunger, reducing poverty, creating sustainable marine life, reducing the risk of disasters in coastal areas, and mitigating and adapting to climate change.

The blue economy approach focuses on creative and innovative investments that can ultimately improve the welfare of the community while taking into account environmental sustainability. New types of businesses and employment opportunities can actually be applied around coastal areas. Waste recycling business, for example, can be an alternative solution to clean the environment around the coast, create new jobs, and reduce waste (zero waste). The implementation of the blue economy globally is considered crucial considering that 72% of the total surface of the earth is the ocean. In addition, the sea functions as a source of food providers and climate regulators and earth temperature so that its sustainability needs to be maintained. So that it can be concluded that the principles in the Blue Economy concept are:

1. Innovation and creative
2. Efficiency of natural resources
3. Zero Waste or environment friendly
4. Improve welfare, and
5. Availability in a very long time

2.3 IMTA Development Potential

IMTA based on aquaculture in Indonesia has developed but can only be found partially, for example those who have ponds only cultivate milkfish with seaweed or added with giant prawns as eaters of digestive waste such as feces and feed. Seaweed besides being a source of oxygen for fish during the day and able to utilize inorganic waste as a nutrient for seaweed cultivation. A more complex IMTA is implemented in coastal areas that have a calm current and are suitable for KJA cultivation. The IMTA system is applied using fish, seaweed, mussel in KJA cultivation and provides good results and optimization in the utilization of feed. Indirectly an ecosystem-based approach has been implemented in the form of aquaculture in ponds or other.

The results of the research on the application of the IMTA model in Teluk Gerupuk, Central Lombok by combining the cultivation of tiger grouper, pomfret, and seaweed showed good cultivation productivity, characterized by the growth performance of all good cultivation commodities. Seaweed growth around IMTA units is higher than control seaweed units (distance 2-3 km from IMTA units); is one indication of the efficiency of the utilization of nutrient distribution which is a culture waste from KJA fish which is wasted into the waters. The results of this study show clearly that the application of the IMTA model in the development of marine aquaculture is very relevant both in terms of land use, production, and environmental conditions of the waters. This IMTA development pattern can be applied in locations with limited potential land, but the availability of superior commodities to be developed. The results of this study are expected to be a model for developing aquaculture that is environmentally sound (Radiarta, 2016).

The application of IMTA in Indonesia can be carried out in marine aquaculture areas that utilize KJA as a cultivation facility for culture organisms. Local ecosystems contained in an area can be carried out as compilers in the IMTA system, because local ecosystems have better adaptation than outside introduced organisms. Local ecosystems need to be maintained in order to maintain natural balance, introduction from the outside will have a bad influence on ecosystem damage such as the spread of diseases and basically organisms in Indonesia's marine ecosystems have high economic value compared to others. The application of IMTA to this idea is carried out in the waters of the reef or bay which have relatively calm currents. Organisms derived from local ecosystems that are utilized are grouper, snapper and baronang fish, because these three fish have high economic value and hatchery of these reef fish has been known so that the supply of seeds as a cultivation element has been fulfilled. Organisms in local ecosystems that act as organic extractive species are mussel, sea urchins, sea cucumber and abalone which are able to utilize the remaining food and feces in KJA cultivation, because naturally these types of organisms are found in Indonesia, especially abalone which has been successfully cultivated. Green mussels and blood clams have been able to be cultivated well in almost all waters in Indonesia so that in their utilization there is no difficulty especially related to hatchery, the ability of shellfish as a feeder filter can utilize suspended particles. Marine plants such as seaweed that are easily cultivated in Indonesia such as

Euchema sp and Gracilaria sp have high economic value and can be useful as inorganic absorbents or wastes in the form of solutions in cultivation systems so that they can be utilized.

The type of organism in the local Indonesian ecosystem for detritive invertebrates is very large, namely the type of sea cucumber pandan (ananas Thelonota), white (Holothuria scabra) and koro (Microtlele nobelis) which are commonly found in the waters of Banyak island, Nanggroe Aceh Darussalam which have been able to be cultivated in almost all parts of Indonesia and has a high price in the world market (Badan Rekonstruksi, 2007). The type of abalone that can be used in Indonesia is a type of black abalone that is cultivated in the Marine Aquaculture Centre in Lombok and many types of porcupine sea urchins are found naturally in the waters so that they can be used directly in the IMTA cultivation ecosystem. The types of seaweed used are Euchema sp and Gracilaria sp which naturally exist in Indonesian waters and have been cultivated by the community both in longline and rafts (Badan Rekonstruksi, 2007).

The term IMTA, is more specific requiring two or more species at different trophic levels to be grown simultaneously in close proximity to each other. This system exemplifies a natural ecosystem function and allows the farmer to get more use out of the same amount of food and energy put into a monoculture system. Although IMTA is not species-specific, many definitions typically identify finfish as the highest trophic level organism, or strictly state that "IMTA is the culturing of fed finfish in combination with other species that filter waste particulates and dissolved nutrients, thereby reducing organic discharge and expanding the economic base of a farming operation.

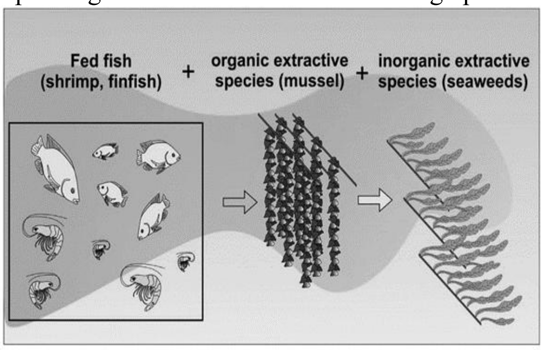

Figure 1: Proposed IMTA for adoption in coastal Bangladesh.

In this case the IMTA method used is utilize nitrogen sequestering species, like shellfish and seaweeds, to take up excess particulate and dissolved wastes expelled by finfish (or shrimp) in an aquaculture setting. This method attempts to replicate a natural ecosystem where the energy output of one trophic level is transferred to the next, lower level. In doing so, waste previously deposited in the water as lost profit can be captured and transformed into another sellable product.

Growing shellfish and seaweed together are less popular worldwide than a complete IMTA system because of the reduced incentive to improve the conditions brought about by the aquaculture system itself. Research has shown, however, that these lower trophic IMTA systems can still have a positive impact on the water quality, especially near commercial facilities, and can still act as an additional revenue for the facility (Soto, 2009).

The coastal aquaculture sector in Bangladesh is particularly vulnerable to climate change. Different climatic variables, including cyclone, drought, flood, rainfall, salinity, sea level rise, and sea surface temperature have had adverse effects on land-based prawn and shrimp farming. Open-water IMTA could be developed to cope with the challenges of vulnerability to the effects of climate change on coastal aquaculture. There are great opportunities for the development of IMTA in coastal Bangladesh as an ecosystem approach for adapting to climate change. The prospects for the development of IMTA in coastal Bangladesh are positive due to environmental and economic benefits. The adoption of IMTA in coastal Bangladesh could reduce ecological effects of shrimp culture on the Sundarbans mangrove forest as well as reduce pressure from capture fisheries. IMTA in coastal Bangladesh has great potential for increasing food production, income, and livelihood opportunities. It could also increase export earnings and economic growth of the country (Ahmed & Glaser, 2016).

IMTA in Canada uses mussels, salmon and seaweed. Utilization of waste from leftover salmon and feces can be absorbed by mussels in the form of suspension or small POM and mussels will undergo metabolism in the form of ammonia and the addition of ammonia can come from fish as a result of metabolism. While inorganic waste in the form of ammonia will be used by seaweed as a nutrient in photosynthesis so that seaweed is able to grow and develop (Jinguang et al, 2009).

IMTA in coastal open-waters may not be affected by flood, sea level rise, and freshwater scarcity as a result of drought and rainfall variation. Open-water IMTA can maintain water quality (Largo et al, 2016), and thus, reduce parasite infestations and disease outbreaks by water currents. Moreover, mussels and seaweeds in IMTA can remove nutrients which in turn reduce the growth of pathogens and toxic algae (Sreejariya, 2011). IMTA systems absorb excess nutrients, and thus, reduce eutrophication. IMTA with finfish and shellfish can remove up to 54% of particulate nutrients (Reid et al, 2010), and seaweeds can remove up to 60% of dissolved nitrogen and phosphorus (Huo et al, 2012).

In climate variables such as cyclone, drought, floods, rainfall, salinity, sea level rise and sea surface temperature to the impacts on land-based coastal aquaculture include:

1. Reduce photosynthesis, reduce O_2, limit primary productivity
2. CO_2 emissions, low water pH, increase waste metabolites
3. Changes in water salinity and habitat patterns
4. Changes in water temperature, hinder ecological interactions
5. Deteriorate water quality by pollutants, water turbidity, erosion, and sedimentation.
6. Reduce water levels and decline fish habitat by drought and rainfall variation.
7. Inundation of ponds, prevalence of parasites and diseases.

Whereas if using the coastal open-water IMTA method, the advantages are as follows:

1. Seaweed in IMTA produces O_2 by photosynthesis
2. Seaweed absorbs CO_2 and shells sequester carbon in its shell
3. IMTA is related to euryhaline species that tolerate wide range of salinity
4. Seaweed and shellfish can withstand water temperatures through biofiltration
5. Seaweed and shellfish make clear water by accumulating pollutants, sediments, and suspended particles
6. Coastal open-water IMTA may not affected by drought and rainfall variation
7. IMTA may not be affected by flood and sea level rise; reduce parasite infections and disease outbreaks by maintaining water quality.

3 RESULT & DISCUSSION

From the results of the discussion and data above we can find out about the coastal open water method by Integrated Multi-Trophic Aquaculture (IMTA) which is highly recommended to be carried out in marine culture in Indonesia in order to improve the welfare of the community, especially coastal areas. In addition, the results obtained are also more profitable than monoculture cultivation. application of strategies in the application of IMTA in Indonesia. IMTA in Indonesia can be developed in the form of a sustainable and environmentally friendly aquaculture industry. IMTA in Indonesia is very appropriate to be implemented in coastal or coral areas because the area has been damaged due to marine cultivation or fisheries activities that are not environmentally friendly. Nutrients in the form of feces and leftovers will be given in the form of solids and will be directly by sea cucumbers or sea urchins or indirectly through the growth of seaweed, phytoplankton and benthos and then utilized by abalone and sea cucumbers. The remaining results are suspense and phytoplankton are used by shellfish so that all waste can be utilized. Organisms that can be utilized are very diverse depending on the region of the archipelago, for example the reef area includes grouper, red snapper and Napoleon fish, as carnivorous organisms or high-level trophic levels. Every fishery activity provides waste, therefore waste can utilize the surrounding organisms or naturally found in the area such as mussel, sea urchins, sea cucumbers and abalone. Then also the utilization of the type of shellfish as trophic level of low-level eaters or reducing waste, shellfish that are used not only shells that can be consumed but pearl shells that have high economic value. Waste in inorganic form can be used in the form of nutrients by seaweed using the longline method or raft method according to the characteristics.

Open water IMTA is very in line with the concept of blue economy because open water IMTA can maintain water quality, and thus, reduce parasitic infestations and disease outbreaks by the flow of water. In addition, shellfish and seaweed on IMTA can eliminate nutrients which in turn reduce the growth of toxic pathogens and algae. The IMTA system absorbs excessive nutrients, and thus reduces eutrophication. IMTA with fish and fish skin can eliminate up to 54% of particulate nutrients, and seaweed can eliminate up to 60% dissolved nitrogen and phosphorus and is one indication of the efficiency of utilization of nutrient distribution which is a culture waste from KJA fish wasted into the waters. The results of this study show clearly that the application of the IMTA model in the development of marine aquaculture is very relevant both in terms of land use, production, and environmental conditions of the waters. This IMTA development pattern can be applied in locations with limited potential land, but the availability of superior commodities to be developed. The results of this study are expected to be a model for developing aquaculture that is environmentally sound (Radiarta, 2016). Adoption of IMTA on the coast of Bangladesh can reduce the ecological effects of shrimp cultivation in the Sundarbans mangrove forest and reduce pressure from fishing. Coastal Bangladesh IMTA has great potential to increase food production, income, and livelihood opportunities. It can also increase export earnings and economic growth in the country.

4 CONCLUSION

IMTA in Indonesia is very appropriate to be implemented in coastal or coral areas because the area has been damaged due to marine cultivation or fisheries activities that are not environmentally friendly and environmentally friendly. The open water IMTA method applied in Bangladesh can be applied in Indonesian marine waters because the aquaculture sector in Indonesia is very vulnerable to climate change. Different climate variables, including cyclones, droughts, floods, rainfall, salinity, sea level rise, and sea surface temperatures have adverse effects on land-based shrimp and shrimp. Open-water IMTA can be developed to overcome vulnerability challenges to climate change impacts on coastal cultivation. There is a great opportunity for the development of IMTA on the Indonesian coast as an ecosystem approach to adapt to climate change. Prospects for the development of IMTA on the Indonesian coast are positive due to environmental and economic benefits. The advantages of the coastal open-water IMTA method are as follows:

1. Seaweed in IMTA produces O_2 by photosynthesis
2. Seaweed absorbs CO_2 and shells sequester carbon in its shell
3. IMTA is related to euryhaline species that tolerate wide range of salinity
4. Seaweed and shellfish can withstand water temperatures through biofiltration
5. Seaweed and shellfish make clear water by accumulating pollutants, sediments, and suspended particles
6. Coastal open-water IMTA may not affected by drought and rainfall variation
7. IMTA may not be affected by flood and sea level rise; reduce parasite infections and disease outbreaks by maintaining water quality

So that the IMTA implemented in Bangladesh can also be applied on the Indonesian coast with innovation and creativity in order to improve seaweed cultivation that is efficient, environmentally friendly, utilizing other ecosystems that are mutually beneficial, improving the economic welfare of the community, and availability in a long time in accordance with the economic concept blue.

REFERENCES

Ahmed, N. & Glaser Marion, 2016. Can “Integrated Multi-Trophic Aquaculture (IMTA)” Adapt Climate Change in Coastal. *Ocean & Coastal Management,* pp. 120 - 131.

Badan Rekonstruksi dan Rehabilitasi, 2007. *Laporan Akhir Penyusunan Budidaya Laut di Pulau Banyak dan Simeleu,* PT. Awamura Internasional. Jakarta.

Blue Economy Project, 2016. *Blue Economy for a Healthy Mediterranean-Measuring, Monitoring and Promoting an Enviromentaly Sustainable Economy in the Mediterranian Region,* Scooping Study.

Huo, Y. et al., 2012. Bioremediation efficiency of Gracilaria verrucosa for an integrated multi-trophic aquaculture system with Pseudosciaena crocea in Xiangshan harbor, China. *Aquaculture,* pp. 326 - 329, 99 - 105.

Jinguang, e. a., 2012. *Development IMTA (Integrated Multi Trophic Aquaculture) in Sungo Bay, China. Yellow Sea Fisheries Research Institute, Qingdao.* China.

Largo, D., Diola A.G & Marabol M.S, 2016. *Development of an Integrated Multitrophic Aquaculture (IMTA) System for Tropical Marine Species in Southern Cebu, Central Philippines,* pp. 67 -76.

Pietrack, e. a., 2009. *Potential Disease Risks and Benefits on a Cold Water IMTA Farm,* Aquaculture Research Institute, University of Maine. Maine.

Radiarta Nyoman, I. & et al, 2016. Performa Komoditas Budidaya Laut Pada Sistem Integrated Multi-Trophic Aquaculture (IMTA) di Teluk Gerupuk, Lombok Tengah, Nusa Tenggara Barat. *Jurnal Riset Akuakultur,* Volume I, pp. 85 - 87.

Reid, G. et al., 2010. Absorption efficiency of blue mussels (Mytilus edulis and M. trossulus) feeding on Atlantic salmon (Salmo salar) feed and fecal particulates: implications for integrated multi-trophic aquaculture. *Aquaculture 299,* pp. 165-169.

Soto, D; Food and Agriculture Organization of the United Nations, 2009. *Integrated mariculture: A global review,* Food and Agriculture Organization of the United Nations. Rome.

Sreejariya, P., Gallardo W & Dabbadie L, 2011. *The Role of Integrated Multi-trophic Aquaculture (IMTA) in Climate Change Mitigation and Adaptation,* Asian Institute of Technology. Bangkok.