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DISSEMINATION OF SUSTAINABLE INTEGRATED MULTI TROPIC AQUACULTURE(IMTA) AS A SATO UMI MODEL TO IMPROVE PRODUCTIVITY AND ENVIRONMENT OF THE INDONESIAN COASTAL AREA

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Abstract.
The dissemination of sustainable Integrated Multi Tropic Aquaculture (IMTA) Sato Umi model within coastal area of Indonesia has been applied by development the experimental model and socialization through workshop and training programs. The result of preliminary experiment that conducted in 2010 has shown the best performance on the biomass productivity of the IMTA Sato Umi model using 4 (four) species cultivated organism (fish, shrimp, algae and green muscle)compare with using 1 (one) to 3 (three) species model. The similar performance also shown on the water quality and the environmental stability. The application of sustainable IMTA Sato Umimodel currently has and is developing from the western (Sabang Aceh) to eastern part (Raja Ampat-Papua) of Indonesia. The model has expanded from the center of first experiment in the northern coastal area of west Java to central Java and Bantaeng in the South Sulawesi of central Indonesia. In the next 5 years, Indonesia is developing the Techno Parks Program in some areas, in which aquaculture and fisheries activities development on the base of Sato Umi concept in the coastal area are involves in this program. The development of Techno Parks are directed as a center application of technology to stimulate the economy in the regency, and a place of training, apprenticeship, technology dissemination center, and center business advocacy for the public. Hopefully the sustainable aquaculture model on the base of Sato Umi concept that has a similar spirit with Techno Park can be applied to support the implementation of Techno Park program in Indonesia

Keywords: *Dissemination, sustainable IMTA, Sato Umi model, Productivity, Environment,Coastal area, Indonesia*

Introduction

Fishery, coastal and marine resources are a potential, promising and can be relied to improve the economy of the people, especially fishermen. On the other hand, a logical consequence of fishery,coastal and marine resources as common property is open to the public access and often used by excessive pressure over the carrying capacity of the resource (over-exploitation) in almost all regions, especially in the Indonesia to the west and also began in eastern part of Indonesia. The existence of various threats and pressures against the existence of fishery resources, coastal and oceans show that the management and utilization has not been balanced by the rate of recovery. As a result, resources are increasingly threatened the existence and carrying capacity decreases in food supply.

Understand the threats and challenges to the existence of global natural resources and their environment, now has developed various concepts to manage and improve their condition by not only making them as an object of human activity, but the subject of human needs that necessary to be managed with a better and wise manner. In line with this thought, fisheries management, coastal and marine areas should be implemented by applying a harmony systems and technology with nature, integrated and engaging the public with respect to the system of values and local wisdom that grow and thrive in the community in accordance with the potential of local resourcesavailability.

To foster harmonious and mutually beneficial relationships between people and nature (symbiosis mutualistic), particularly in the management of fishery resources, coastal and marine, in 2007 the Japanese government has implemented a concept of wise management of natural resources between communities living around the forest, known as SATO-YAMA adopted a SATO-UMI, the relationships between community who life in the adjacent of the coastal fishery resources and marine areas. SATO-UMI is the new concept of sustainable management of fisheryresources in

which human intervention in the management of fisheries resources in the coastal and marine areas can increase the productivity and diversity of fishery resources. In a broader scale, SATO-UMI basic concept can be applied to balance the availability of natural resources as a source of food by maintaining the stability of ecosystems. In line with the growing global paradigm in the face of change and good environmental damage caused by excessive exploitation of natural resources and the consequences of climate change and global warming, it is time for Indonesia to implement the concept of management andutilization of natural resources taking into account the balance and stability of the natural resources and the environment, such as in the concept of SATO-UMI. To support those paradigms, it is necessary to develop a management and utilization concept of fishery, coastal and marine resources wisely, balanced, harmonious, integrated and more productive by developing sustainable aquaculture model as an "Integrated Multi-Trophic Aquaculture (IMTA)".This aquaculture technology was developed on the based bio-recycle system in the idle and marginal brackish water pond. By applying this concept, fisheries resources and the environmentespecially in the coastal areas that have been damaged can be recovered, more productive and biological resources diversity can be increased in a balanced and harmonious to improve the welfare of coastal community.

Material and Methods

- **Experimental design of sustainable Integrated Multi Trophic Aquaculture (IMTA)Sato Umi model.**

The preliminary experiment to clarify sustainable Integrated Multi Trophic Aquaculture (IMTA) Sato Umi model has been conducted in the marginal brackish water pond at the northern coastal area of Karawang, West Java, Indonesia in 2010 as shown in Fig.1 [1]. This experiment was designed on the base of Sato Umi concept by involving coastal community intervention to create the aquaculture sustainable model for improving productivity and increasing biodiversity of coastal area [2]. The experimental design of 4 (four) models using 500 m^2 pond of each model with 3 (three) replications (Fig.1). The model-1 (P-1) contains seed of black tiger shrimp with density 5 shrimp/m^2. Model-2 (P-2) contains seed of tilapia and black tiger shrimp with density 5fish and shrimp/m^2 of each. Model-3 (P-3) contains tilapia and black tiger shrimp with the same density with P-2, with additional algae/seaweed (*Gracillaria, sp*) in the long line system with density of 0.1 kg/m^2 per point. Model-4 (P-4) contains the same composition and density with P-3 of tilapia, black tiger shrimp and algae/seaweed (*Gracillaria, sp*) with additional benthic organism of oyster green mussel (*Pernapiridis, sp*) in the longline system with density 100 g per point, and as a control we used pond without organism.

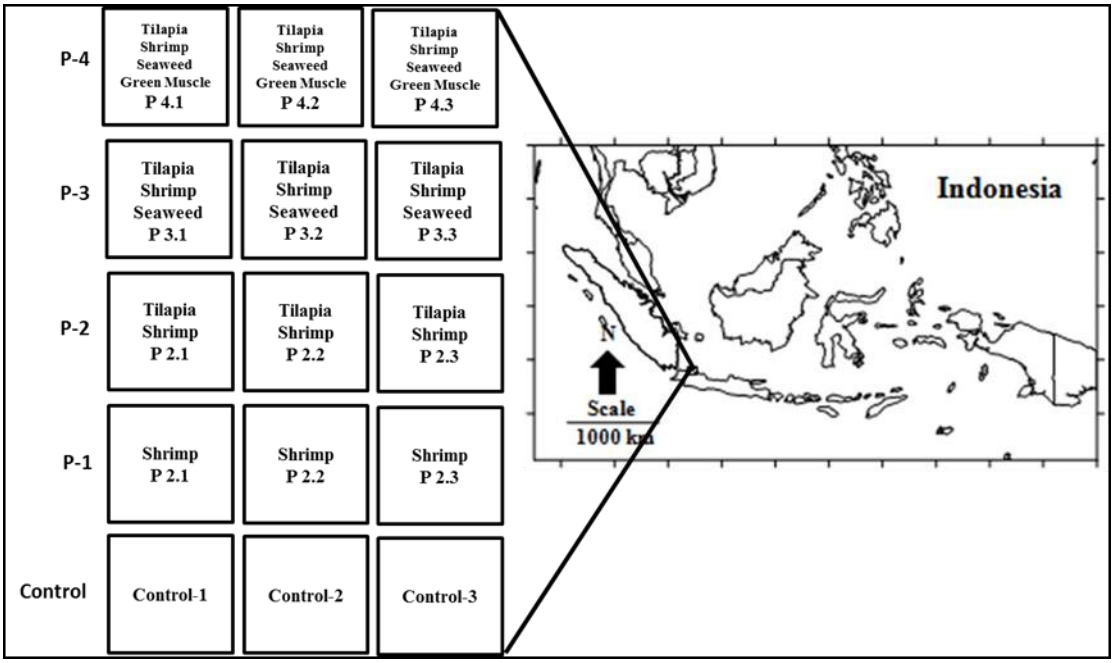

Figure 1. *Location and design of preliminary experimental of sustainable IMTA Sato Umi model at the northerncoastal area of Karawang [1]*

- **Dissemination method of sustainable IMTA Sato Umi model**

To socialize and disseminate sustainable IMTA on the base of Sato Umi concept in the coastal area of Indonesia, workshop and training to improve human capacity of coastal community has been conducted in some areas. Method of dissemination is by providing lecture in class, field trip to some areas of aquaculture and fisheries activities, laboratory analysis and presentation on the seminar and workshop. Participant of the workshop and training come from various level organization of the local, regional and national level, and stake holder that associated with fishery,coastal and marine resources management such as scientist from Agency for the Assessment and Application of Technology (BPPT), Ministry of Marine Affairs and Fisheries (MMAF), Ministry of Research Technology and High Education, Ministry of Forestry and Environment, Ministry of Public Works, Coordinating Ministry for the Economy, Finance and Industry, Coordinating Ministry for People's Welfare, Ministry of Development of Disadvantaged Areas, Ministry for National Development Planning (Bappenas), Ministry of Cooperation and Small Medium Enterprises (UKM), Food Security Agency of the Ministry of Agriculture, Department of Fisheries and Marine Resources, Institute of Aquaculture, Fisheries entrepreneurs, community leaders, the farmers and other relevant stakeholders.

Workshop was also attended by experts from various research institute and university come from overseas that is coordinated by EMECS (Environmental Management of Enclosed Coastal Seas) center and PICES (North Pacific Scientific Marine Science). Research institute and university that was involved are MAFF (Ministry of Agriculture, Forestry and Fisheries), FRA (Japan Fisheries Research and Education Agency), Northwest Pacific Region Environmental Cooperation Center, Maine System University-USA, San Francisco State University, NOAA Fisheries, Kyushu University, Hiroshima University, Yokohama College of Commerce. The expected results of the workshops that organized by BPPT, PICES (North Pacific Marine Science Organization), EMECS (Environmental Management of Enclosed CoastalSeas), MAFF (Ministry of Agriculture, Forestry and Fisheries) and FRA (Fisheries Research Agency of Japan) is to provide inspire and give new spirit to various stake holders to manage and utilize fishery, coastal and marine resources optimally, harmonious, productive and sustainable toensure the sustainability of food supply from fishery, improving the community welfare and localincome.

Result and Discussions

1. Result of the preliminary experiment of sustainable IMTA Sato Umi model

- **Water quality and the environmental stability**

Based on the analysis and evaluation of water quality (temperature, salinity, pH, DO, turbidity, TSS, BOD_5, DIN and DIP) of 4 models brackish water pond and control of the preliminary experimental result of 2010 as shown in Table 1, indicated that water quality for all models is in a good performance to support the aquaculture organism life. Though inland pond located a few hundred meters away from the coastline and there is a channel between pond and sea, but no significant water exchange occur between pond and sea, because water from channel was filled manually to the pond using pump. The interesting situation is seen on the model of P-4 where temperature and DO are relatively high, while salinity and pH are low. High DO concentration of P-4 model exposed the enrichment of DO as response to the availability of algae/seaweed (*Gracillaria, sp*) that produced DO through high intensity of photosynthesis and it is stimulated by high temperature. The almost similar situation was seen on P-3 in which DO concentration was higher than that in P-1 and P-2. High turbidity in P-4 model seems due to high chlorophyll-a, because TSS is low. From this situation it can be concluded that the presence of seaweed in P-4 and P-3 model has improved the water quality.

Table 1. *Water qualities of each brackish water pond model (Sachoemar et al, 2014)*

Brackishwater pond model	Temperature (° C)	Salinity (ppt)	pH	DO (ppm)	Turbidity (NTU)	TSS (mg/l)	BOD_5 (mg/l)
P-1	30.81	24.94	7.92	6.28	121.83	36.50	1.66
P-2	30.77	23.11	7.87	6.27	127.46	22.33	0.71
P-3	30.92	22.48	7.90	6.74	157.08	22.83	0.24
P-4	30.94	22.91	7.91	7.11	177.67	18.00	1.18
Control	30.60	20.30	8.05	6.65	197.00	38.00	0.71

Moreover, based on the data shown in Fig.2, the DIN concentration of P-4 is the lowest even compared to the control. This situation indicates that P-4 containing green muscle as the organic consumer organism and seeweed as an inorganic consumer has contributed on the reduction of DIN concentration through bio-recycle system. In this system, organic material derived from residual feed, fish waste and other sources will be used for seaweed and green

muscle growth. As the result, water quality of P-4 to be more stable compare to the other models. It means that bio-recycle system in the integrated multi trophic aquaculture model worked well on the reduction of DIN concentration of P-4 model. The similar situation was seen on the DO concentration in which P-4 is significantly different with the other models and control. High DO concentration of P-4 is stimulated by availability of seaweed and high temperature that contributed on the intense of photosynthesis. High DO concentration was also shown by P-3 compared with P-1, P-2 and control.The availability of seaweed in P-3 has also contributed on the enrichment of DO concentration. The different situation was seen on the DIP that is no significant different among the models even with control Fig.2. It is indicated that DIP was not a major element that affects aquaculture system in the northern coastal area of Karawang compare to DIN.

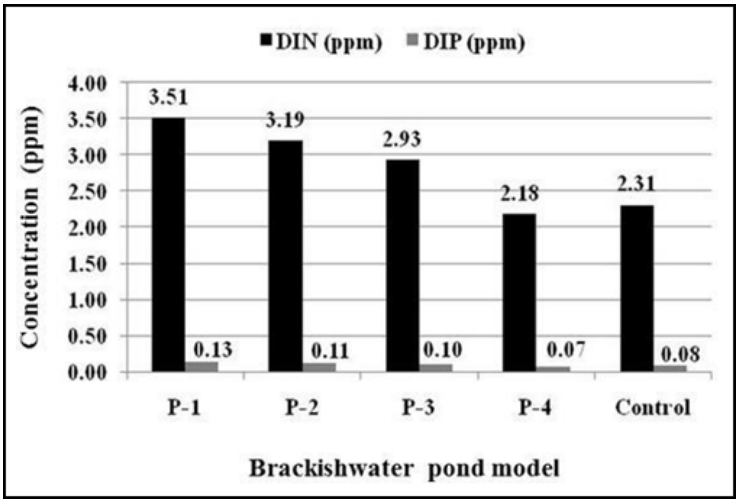

Figure 2. *Mean average of DIN (Dissolve Inorganic Nitrogen) and DIP (Dissolve InorganicPhosphorus) of each brackish water pond model (Sachoemar et al, 2014)*

- **Productivity performance of the sustainable IMTA Sato Umi model**

Performance of the biomass productivity of each experiment model in Fig.3 shows that model of P-4 is the most productive followed by P-3 model, while the water quality stability as shown on Table 2 and Fig. 2 indicated the excellent condition for P-4 model with the lowest concentration of DIN compared to the other models. This condition shows that bio recycle system worked well on P-4 model with containing multi trophic organism to reduce and minimize the organic and inorganic waste from the remaining feed, feces and the other sources on the aquaculture system. The model also was more productive on the biomass production compared to the mono culture or poly culture system as shown on the P-1 and P-2 models with no algae and benthic organism.

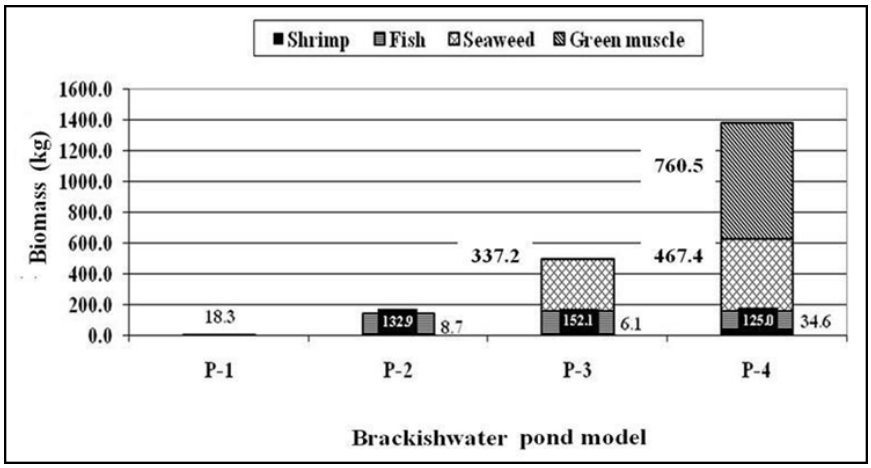

Figure 3. *Productivity performance of each brackish water pond model (Sachoemar et al, 2014)*

- **Dissemination of sustainable IMTA Sato Umi model.**

To socialize and disseminate of sustainable IMTA Sato Umi model in Indonesia, the first International Workshop on Sato Umi have implemented in March 2013 and the International Training in March 2014 at Karawang. The second workshop was held in November 2014 at Pekalongan, Central Java, and the third workshop was held on 7-8 October 2015 in Jakarta that isfollowed by field trip to marine aquaculture and fisheries activities at Seribu Islands of the Northern Coastal Area of Jakarta (Fig.5). Results from the workshop are expected will inspire and give new spirit to the various stakeholders to manage fisheries, coastal and marine resources optimally, harmonious, productive and sustainable to ensure the stability of the fishery-food supply and ecotourism to improve the coastal community welfare and economic growth of local government. In the next 5 years programs, Indonesia is developing the Techno Parks in some areas with aquaculture and fisheries activities in the coastal area involves in this program. Development of the Techno Parks are directed as a center application of technology to stimulate the economy activity in the regency/city, and a place of training, apprenticeship, technology dissemination center, and center business advocacy for the public. Hopefully, Sato Umi concept that has a similar spirit with Techno Park can be applied to support the implementation of TechnoPark program in Indonesia. To be more socialized concept of Sato Umi as well as to determine the future development of the sustainable aquaculture, the workshop and training was also held atBantaeng (South Sulawesi) in November 2016. This concept and the model of integrated sustainable aquaculture also will be expanded to the eastern part of Indonesia, such as Sabang (Aceh) and Anambas Island (Riau) in the western and Raja Ampat (Papua) in the eastern part of Indonesia (Fig.6). While in the Java Island has been expanded to the northern part of coastal Java.

Figure 5. *Workshop and training of sustainable IMTA Sato Umi model*

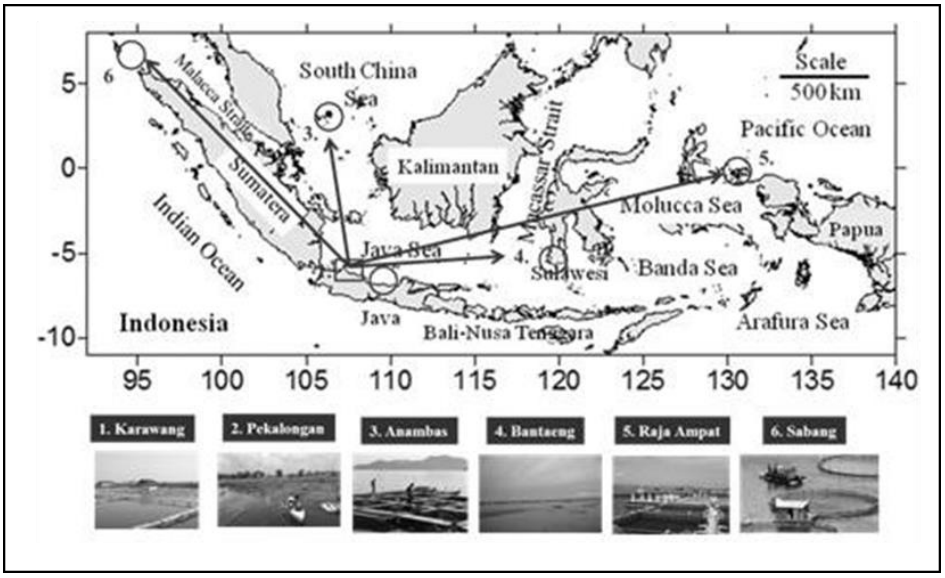

Figure 6*. The development and expanded of sustainable IMTA Sato Umi model in Indonesia*

Discussion

- **Development of sustainable IMTA Sato Umi model**

Sustainable aquaculture model of Integrated Multi Trophic Aquaculture (IMTA) that is developed based on Sato Umi concept is the environment friendly aquaculture (green technology)with zero or minimize waste. Coastal brackish water and marine aquaculture productivity can be improved by using the IMTA technology, in which various commodities such as finned fish, seaweed, sea cucumbers and oyster reared in the similar area and water quality was stable. In this system, organic waste come from food remains and fish feces will be used by oyster and sea cucumber for their growth, while seaweed utilize inorganic nutrients for growing and create an ecosystem balance [3,4]. As the result, productivity of cultivated integrated commodities grows and develop in an optimal and efficient in utilization of marine resources. The integrated sustainable aquaculture technology on the base of Sato Umi, if successfully applied in a whole coastal marginal area of Indonesia, the income of the coastal community of the region and the country's economy as a whole will increase.

Development of the integrated sustainable aquaculture technology on the base of Sato Umi by using high economics value varieties of aquaculture commodities such as tilapia, milkfish, shrimp, snapper and grouper that is combined with seaweed, sea cucumbers and oyster in the coastal marine aquaculture area is a strategic activity to be promoted. The Integrated Multi Trophic Aquaculture (IMTA) technology that is developed on the base of bio recycle system and Sato Umi concept is a model that is suitable to be developed, to support the revitalization program for increasing aquaculture export product, public consumption and protection of fishery resources. Green Technology in the field of aquaculture was developed to overcome the problem of environmental degradation. By developing a model of environmentally friendly aquaculture as anintegrated multi-trophic aquaculture, the productivity of marginal brackish water pond in the coastal area is expected can be improved and quality of the environment can be well maintained and sustained. In the integrated multi-trophic aquaculture (IMTA) with bio recycle system, the organic material from remaining feed, fish waste and the other sources can be reused for oyster growth, while inorganic material for seaweed growth. The integrated multi trophic aquaculture is expected to solve the problems in maintaining the stability of aquatic ecosystems and improve productivity of marginal brackish water ponds within Indonesian coastal waters. It is already evident in the pond of P-4, where algae/seaweed (*Gracillaria sp*) and oyster green mussel (*Pernapiridis, sp*) that were cultivated with black tiger shrimp and tilapia grew well as well as water quality was stable. In this system, inorganic and organic wastes from remaining feed and feces of tilapia and shrimp are reused for seaweed and oyster growth. The existence of seaweed has also enriched the dissolved oxygen and made the aquatic ecosystem more health and stable tomaintain the cultivated organism.

In the view point of cultivated organism quantity, applying the integrated multi trophic aquaculture model using polyculture system has provided good performance on the optimize utilization of marginal brackish water pond improving productivity. Moreover, water quality andaquatic ecosystem health can also be maintained naturally

compared to the monoculture and non-integrated multi trophic aquaculture system. The similar models using different organisms of the integrated multi trophic aquaculture model, is expected to be developed to improve and increase the productivity of marginal brackishwater pond in a sustainable manner. The result of experiment has shown that P-4 containing 4 cultivated organisms as an integrated multi trophic aquaculture model was the most productive aquaculture system with the most stable water qualitycompared to monoculture and polyculture non integrated multi trophic aquaculture system. This result indicates that the aquaculture system with integrated multi trophic polyculture will be morebenefit to sustain the aquaculture system in the coastal area and more productive to provide financial benefits for the coastal community compared to the monoculture and polyculture without algae and benthic organism as shown in P-1, P-2 and P-3. With integrated multi trophic aquaculture models, the risk of failure aquaculture business is expected to be reduced, because at least one or more cultivation organisms are still expected to be harvested. The farmer can also reduce the risk of capital farming and maintain the coastal area to sustain aquaculture activities with the natural balance.

- **Dissemination and development of sustainable aquaculture model of Sato Umi**

  Indonesia has 1.2 million ha of brackishwater pond area, but only 37.5% of them are used for aquaculture activities. While marine aquaculture area which can be developed for cultivation of seaweed in the shoreline area up to 4 miles and cage for area over 4 miles with commodity snapper, grouper, pomfret stars, abalone or tuna reached 4.58 million hectares is only used about2 percent. The low utilization of brackishwater pond is generally caused by environmental damage due to the excessive exploitation by intensive aquaculture activities during the period of 1980s. It is well known that more than two decades ago, the northern coastal Area of Java was to be a center of shrimp production and an important region for the economic growth of the western Indonesia. However, the rapid development of shrimp farming, industry and housing in the region has caused environmental damage [5]. Since 1985, area along the northern coastal of Java have gradually been converted into shrimp ponds with intensification system. In the early stages, this system has contributed greatly to the production of shrimp for the region with an average productivity of more than 4 tons/ha. However, after a decade, shrimp productivity decreases dramatically to less than 1.5 tons/ha. Rapid development of shrimp farming that was followed by massive mangrove deforestation which actually serves as a buffer zone to degrade an organic waste as well as an intensified used of feed and drugs has caused an excess on the decreasing of water quality, aquatic environmental and the carrying capacity in the region. As a result, various diseases threatened of shrimp lives from early stage to pre-harvest. Various environmental damage caused by intensive shrimp farming in some areas have been reported [6]. In line with the growing global paradigm in the face of change and good environmental damage caused by excessive exploitation of natural resources and the consequences of climate change and global warming, it is time for Indonesia to implement the concept of management and utilization of natural resources taking into account the balance and stability of the natural resources and the environment, such as in the concept of Sato Umi as promoted by Yanagi (2008).To support those paradigms, it is necessary to develop a management and utilization concept of fishery, coastal and marine resources wisely, balanced, harmonious, integrated and more productive by actively involving the community as in the concept of Sato Umi to improve productivity of the marginal brackish water pond and marine aquaculture in the coastal area. An integrated and environmentally friendly farming technology model such as the Integrated Multi- Trophic Aquaculture (IMTA), can be applied to improve the productivity of marginal brackishwater pond and marine aquaculture by increasing the diversity product through biorecycle system to ensure the sustainable utilization of brackishwater pond and marine aquaculture in the coastal area. A sustainable model of Integrated Multi-Trophic Aquaculture (IMTA) which is applied in the brackishwater pond and marine aquaculture in the coastal area is shown in Fig.4. The model for brackish water has been applied at breackishwater pond area at Karawang (West Java) and Pekalongan (Central Java), while for marine culture area will be applied at Bantaeng (South Sulawesi), and will be expanded to Sabang in the west and Raja Ampat in the eastern part of Indonesia.

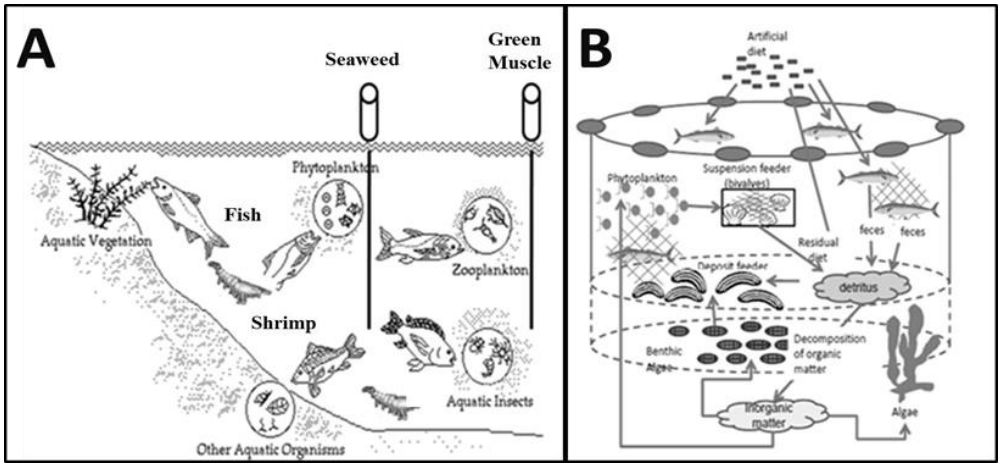

***Figure 4**. Sustainable model of IMTA for brackish water (A) and marine aquaculture (B)*

The sustainable aquaculture model by applying Sato Umi concept has been applied within coastal area of Indonesia from the center of first experiment in the northern coastal area of west Java to central Java (western Indonesia), Bantaeng in the South Sulawesi of central Indonesia. The similar program has also been proposed for Sabang (Aceh) in the western and Raja Ampat (Papua) in the eastern part of Indonesia. In the near future, the sustainable model of aquaculture is expected to be applied in the Techno Parks which is developed by government and can be expanded to whole coastal area of Indonesia to stimulate and accelerate the economic growth andimproving human well-being within the Indonesian region.

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