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The Simulation of Integrated Multi-Trophic Aquaculture Bio-floating Net Cages Model Based on Eco-technology Engineering Design Laboratory

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ABSTRACT : The rapid development of floating net cages has positively and negatively impacted Indonesia's aquatic environment. Although this phenomenon significantly impacts local revenues and income for local fish farmers, the presence of floating net cages contaminates the water column. The bio-floating net cages have been proposed as a solution to mitigate water pollution in the previous study. By using organic waste decomposition micro-bacterial technology at sub-based buoyancy, sedimentation in aquatic environments can be reduced. This study aims to generate a model of bio-floating net cages based on an eco-technology engineering design laboratory through contextual-interpretative-design development methods. The output of this study depicts a simulation of a technical model of integrated multi-trophic aquaculture bio-floating net cages. The findings of this study are expected to be beneficial for the development of fish farming as well as knowledge to support the resilience of the aquatic environment in Indonesia.

KEYWORDS – Bio-floating net cages, Eco-technology, Integrated multi-trophic aquaculture, Simulation

I. INTRODUCTION

Indonesia is known as a maritime country with a 5.8 million square kilometre area of territorial waters [8]. Fish farming has been a source of local revenues and income for local fish farmers for a long time. Floating net cages are commonly used in fish cultivation systems. Floating net cage aquaculture has spread excessively in Indonesia, and fish farming waste is escalating into aquatic environmental pollution [1][2][3][4][16]. Floating net cages fish farming is usually found in small water bodies with no runoff, such as reservoirs. The intensive feed supply leads to deleterious effects, such as eutrophication and sedimentation in the water column. Polluted aquatic environments in Indonesia can be found at reservoirs (Saguling and Jatiluhur reservoirs in West Java are chosen to be the pilot study). Excessive suspended and colloidal minerals can cause turbidity and impact the water quality. The lack of transparency makes it difficult for the sunlight to penetrate the water column. This condition gets worsened during dry season as the methane gas is increasing [18]. The rising of methane gas causes the death of fishes.In the previous study, bio-floating net cages are proposed as a solution to the problem. Bio-floating net cages with integrated multi-trophic aquaculture (IMTA) system (or bio-keramba tumpangsari in Indonesian) are environmental-friendly floating net cages by applying the eco-technology to decompose the fish farming waste (or BKARTLA, an abbreviation of bio-keramba ramah tata lingkungan air in Indonesian) [8][17]. This study is initiated to generate a technical model of integrated multi-trophic aquaculture bio-floating net cages based on eco-technology engineering design laboratory. The technical model of integrated multi-trophic aquaculture bio-floating net cages is expected to be beneficial for the development of environmental-friendly fish farming in Indonesia.

II. LITERATURE REVIEWS

Floating Net Cages : Floating net cage is a popular and ideal system in fish farming. Because its convenience and extensive use in freshwater fish farming, floating net cage are commonly used in reservoirs which have more depth than rivers or ponds [6].The floating net cages come in various shapes and sizes. The types and the sizes of the fish and the depth of the waters are the main factors in determining floating net cages variation. Several types of floating net cages that are commonly used in fish farming, namely square shape net cage, round shape net cage, and octagonal shape net cage [7][11] (Fig 1).

Figure 1 Variation of floating net cages
(Source: PT Gani Arta DG 2015; Permadi 2016)

The floating net cages is constructed from six main components, namely framework, net, floatation device, ballast, and anchor. The construction of floating net cages framework in Indonesia is usually made of natural resources such as bamboo and wood. This framework is then given a net and a floatation device, such as a plastic drum so that the net will remain floating in the water. The net (or usually known as hapa or waring in Indonesian) is usually made from small woven monofilament plastic strings.

The Principle of Floating : As stated in Archimedes' principle, "a body immersed in a fluid is subjected to an upwards force equal to the weight of the displaced fluid", the buoyant principle is then used to calculate the buoyancy of the IMTA bio-floating net cages structure (Fig 2). The tensile lateral force resulting from the pressure of the water stream will cause movement and the enforced balance of vertical force causes the float situation. The flow of water influences the dynamics of the water surface and it causes horizontal and vertical thrust force. Differences in elevation and wind blowing on the water's surface create wave motion. These are the main causes of the horizontal force.

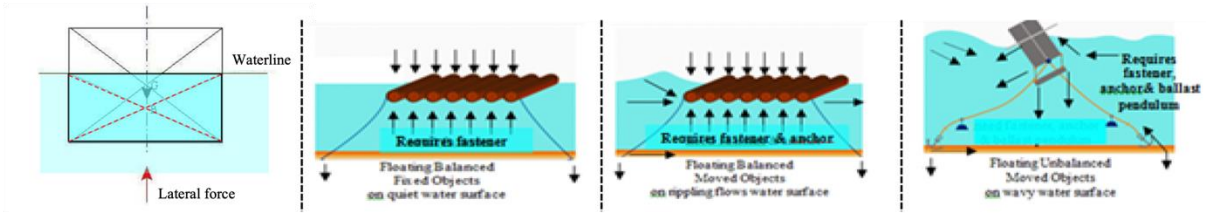

Figure 2 Buoyancy principle
(Source: www.google.com 2010)

III. METHODOLOGY

This study focuses on generating a technical model of bio-floating net cages with integrated multi-trophic aquaculture system based on eco-technology engineering design laboratory. The methodology of this research applies a resiliency-sustainability approach based on Geo-Bio-Cultural-Diversity synergy for Saguling and Jatiluhur reservoirs through contextual-interpretative-design development approach [15] (Fig 3).

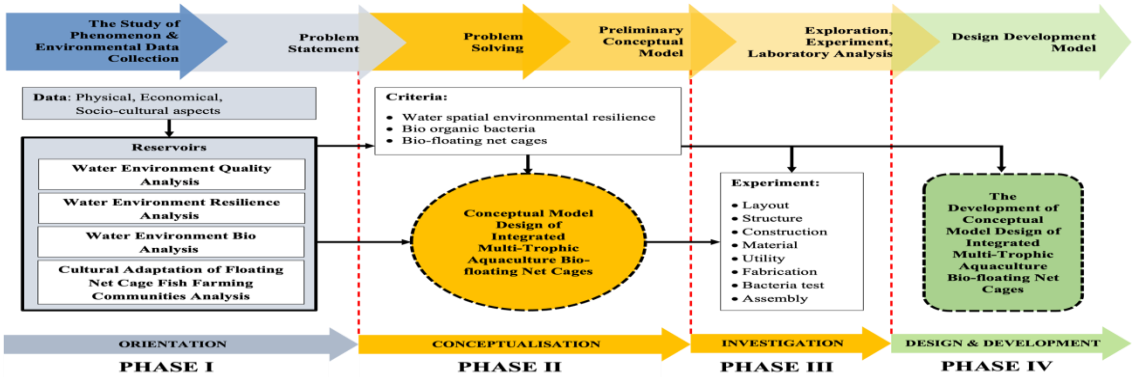

Figure 3 Research framework
(Source: Kusliansjah 2018)

IV. RESULTS AND DISCUSSION

The Design Principles of Integrated Multi-Trophic Aquaculture Bio-floating Net Cages

The principles of integrated multi-trophic aquaculture on floating net cages : IMTA in fish farming is a concept that combines two or more species of fish from different trophic levels to have a mutualistic relationship in food chain systems, in the same net at the same time. IMTA floating net cages utilises a double-layer net in one net cage system, allowing the fish farmers to cultivate two types of fish (for example, carp and tilapia) simultaneously. The food waste and faeces of carp cultivated in the inner layer of the floating net cage will be eaten by tilapia in the outer layer. In addition to aquatic environment pollution prevention, IMTA floating net cages is beneficial to speed up the harvesting process of fish farming. This opportunity means harvesting two species of fish several times in one year.

The principles of environmental-friendly integrated multi-trophic aquaculture floating net cages : As stated in the previous study, the principle of environmental-friendly IMTA floating net cages is a combination of a traditional floating net cages system and a "bio-septic tank" system for fish farming waste. At the base of the outer layer of bio-floating net cages, the food waste and faeces of fish container is constructed. The food waste and faeces of fish container is made from a tray of tarpaulin. The further mechanism of IMTA bio-floating net cages is that the fish food waste and faeces collected in the container will be processed by the "bio-septic tank" at the base of the floating net structure. Localised micro-bacteria compounds are placed in the "bio-septic tank", and they will decompose the incoming fish farming waste. Fish farming waste consumed by the micro-bacteria no longer produces sludge, noxious gas, and odours so that it will not contaminate the water column. The "final waste" is in rainwater quality after being processed by filter layers in the "bio-septic tank". The micro-bacteria will work productively until it reaches its lifespan. By the end of its productive cycle, the new compounds of localised micro-bacteria will be replaced in the "bio-septic tank".

The five concepts of environmental-friendly IMTA aquaculture on bio-floating net cages are stated (Fig 2), as follows:

1. The dimension of main floating structure is 7x7 m;
2. The nets are suspended from the floating structure at a depth of 3-4 m;
3. The food waste and faeces container in the form of a tray of tarpaulin is constructed at the base of the net structure;
4. The construction of a "bio-septic tank" is hung at the centre of the food waste and faeces container;
5. The "bio-septic tank" serves as a pendulum for the floating structure.

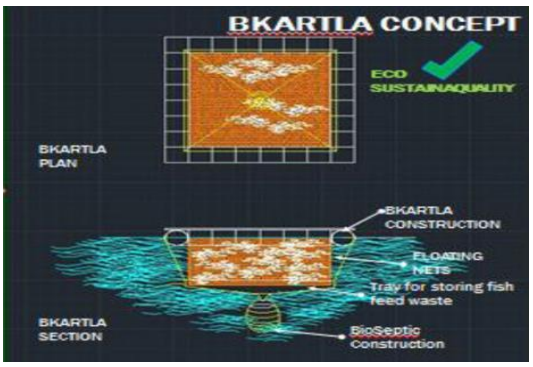

Figure 4 Environmental-friendly integrated multi-trophic aquaculture floating net cages
(Source: Kusliansjah 2018)

The Integrated Multi-Trophic Aquaculture Bio-floating Net Cages Based on Eco-Technology Engineering Design Laboratory

Floating foundation structure : The structure design concept of IMTA bio-floating net cages is a strong, stable, durable yet lightweight floating structure. Based on the buoyancy principle, the ideal shape of IMTA bio-floating net cages foundation structure is determined. The context of the reservoir environment is very likely to be strongly hit by horizontal forces from wind, rain, floods, and storm waves. In addition to the environmental

context, the stability and balance against the rolling motion due to the vertical forces are essential to be taken into account. Even though a circle is the most effective shape for aerodynamics, a square is recommended to be the basic shape of IMTA bio-floating net cages foundation structure because it is both effective aerodynamically and efficient spatially. The floating foundation structure components are in octagonal and square shape of air hollow cushion. The diameter of octagonal air hollow cushion is 60 cm and its height is 30 cm. The dimension of the square air hollow cushion is 25 x 25 x 30 cm. The floating foundation structure are interlocking components and assembled into a two-layer floating frame where nets construction is attached (Fig 4).

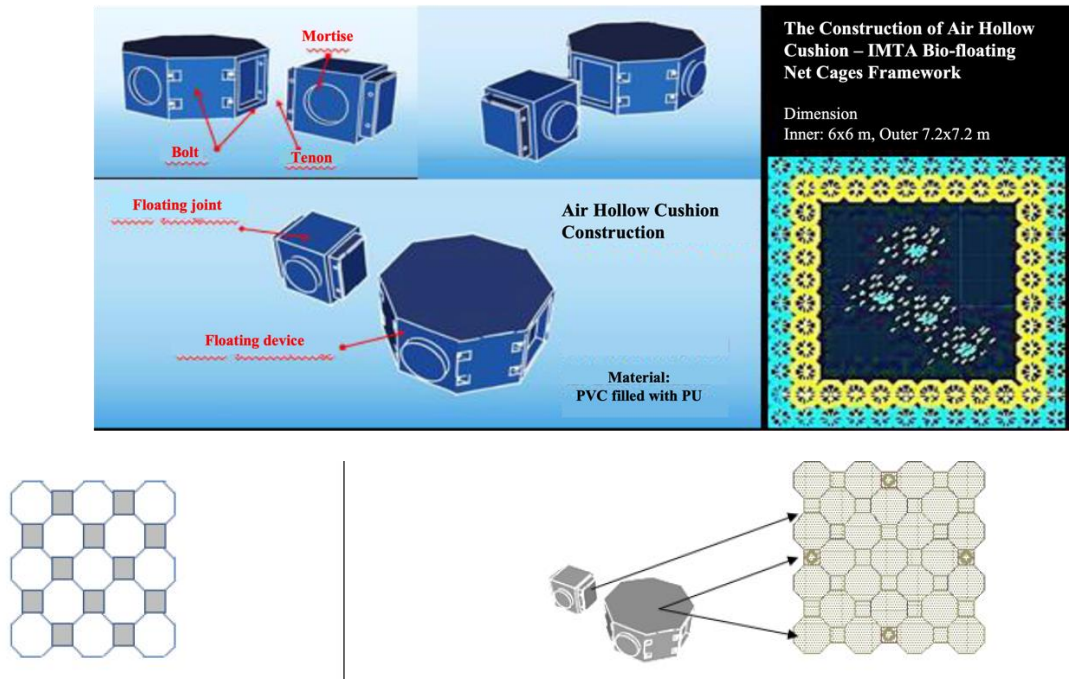

Figure 5 The principle of floating foundation in integrated multi-trophic aquaculture bio-floating net cages (Source: Kusliansjah 2018)

The structure of floating foundation of IMTA bio-floating net cages is a fabricated assembled components made from Polyvinyl chloride (IUPAC: Poly (chloroethane diol)), or commonly abbreviated as PVC filled with polyurethane foam (PU) (Fig 5). PVC is an environmental-friendly material which is easy to clean. In the contrary of the traditional materials such as wood or bamboo, using PVC material for the floating foundation structure provides a longer lifespan and the damage of natural environment can be reduced. In addition to a strong, durable, and non-flammable material, PU is relatively inexpensive and available nation-wide.

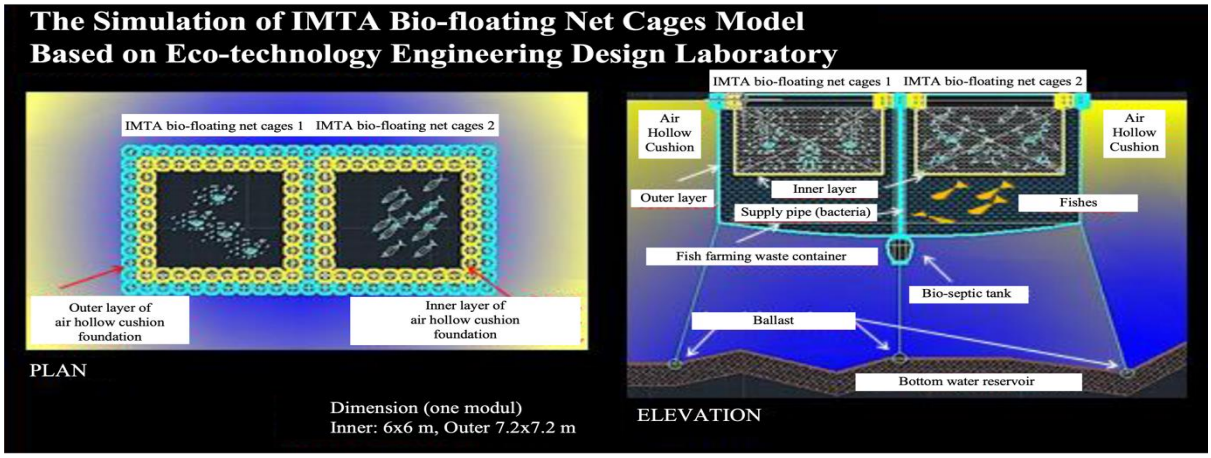

Figure 6 The principle of IMTA bio-floating net cages model (Source: Kusliansjah 2018)

The construction of IMTA bio-floating net cages should consider the socio-economic aspects of local community of fish farmers and the aquatic environment. Hence, the proposed floating foundation structure of IMTA bio-floating net cages has an opportunity to be developed into an industrial product. The purpose of mass-produced proposed floating foundation structure component of IMTA bio-floating net cages is to push the production price down. This advantage will make it possible for the traditional fish farmers to afford the proposed environmental-friendly floating foundation structure component.

Bio-septic tank : The IMTA bio-floating net cages based on eco-technology engineering design laboratory use the bio-septic tank component as found on biosung eco-technology products (www.biosung.com) (Fig 6). The components are then will be modified according to the context.

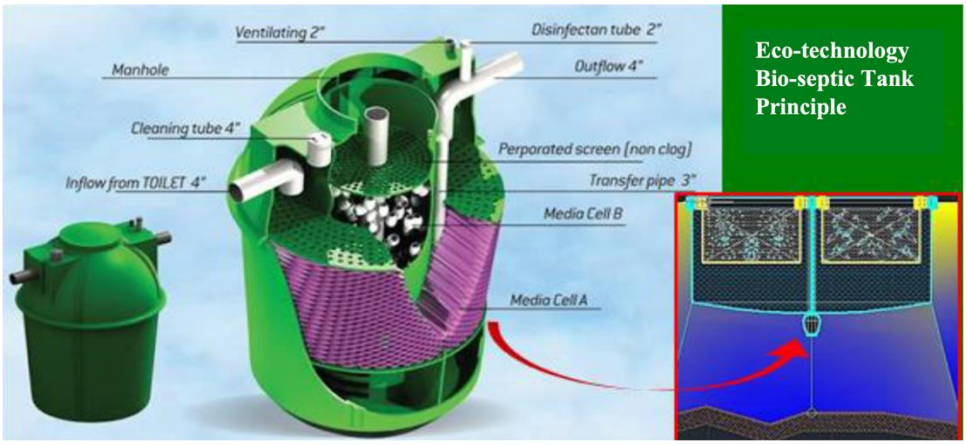

Figure 7 The principle of bio-septic tank of IMTA bio-floating net cages
(Source: Biosung 2018)

V. CONCLUSION

The simulation of an integrated multi-trophic aquaculture bio-floating net cages model based on an eco-technology engineering design laboratory is an improvement to traditional floating net cages for the development of environmental-friendly fish farming in Indonesia. IMTA floating net cages utilises a double-layer net in one net cage system, allowing the fish farmers to cultivate carp and tilapia at the same time. The food waste and faeces from cultivating these two fishes will be collected in a container made of tarpaulin.Furthermore, the fish farming waste collected in the container will be decomposed by localised micro-bacteria in the "bio-septic tank" that is hung at the base of the IMTA bio-floating net cages. The "final waste" is in rainwater quality so that it will not contaminate the water column. The floating foundation structure in octagonal and square shapes are interlocking components assembled into a two-layer floating frame where nets construction is attached. PVC filled with PU provides a longer lifespan and it is environmental-friendly so it is chosen to be the main material for floating foundation structure construction.By considering the socio-economic aspects of the local community of fish farmers and the aquatic environment, the proposed floating foundation structure of IMTA bio-floating net cages has an opportunity to be mass produced. This advantage will make it possible for the traditional fish farmers to afford the proposed environmental-friendly floating foundation structure component.

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