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Application of polyculture using stratified double net cage: a case study at Awerange Gulf, Barru, South Sulawesi, Indonesia

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Abstract. This research is aimed to develop aquaculture techniques, particularly the use of stratified double floating net cage (SDFNC) for polyculture to increase productivity, and maintain a healthy water ecosystem for sustainable aquaculture. Installation of SDFNC was done at the Gulf Awerange, Barru, South Sulawesi. The polyculture system consisted of macro algae (*Euchema cottoni*), rabbitfish (*Siganus* sp.), black tiger shrimp (*Penaeus monodon*), and Pacific white shrimp (*Litopenaeus vannamei*). Macroalgae was cultivated by binding to the algae using polyethylene strap transversely from the water surface to a depth of 5 m along the edge cage. A number of 50 ind. m^{-3} of rabbit fish were farmed in the bottom net cage; 100 ind. m^{-3} of 12 m^3 in total of PL30 Pacific white shrimp and 50 individuals m^{-3} of 12 m^3 in total of PL30 black tiger shrimps were located in the upper net cage. Biomonitoring was carried out by observing the structure of macrobenthic community. The condition of the water at the farmed area was still within the normal range, both at a depth of 1 m and 5 m from the surface, and 1 m of bottom waters. There was a significantly difference between polyculture and reference site, implying that there was a slight environmental disturbance of sedimentary habitat underneath the farm cage. Overall, the area is considerably suitable for the application of SDFNC, with water current range up to 14.1 cm sec^{-1}. The growth of main biotas represented by *Siganus* sp. and *L. vannamei* farmed using SDFNC exhibited faster compared to monoculture farm, owing to the relatively high values of the relative growth rate (RGR) (2.3-6.2%) and specific growth rate (SGR) (1.05-1.4%).

Key Words: biomonitoring, polyculture, growth rate, *Euchema cottoni*, *Siganus* sp.

Introduction. The biggest potential problem in the aquaculture sector is the increasing number of farming practices that are not environmental-friendly, oriented only on production capacity without regard to the carrying capacity of the environment, impacting in the increase of organic enrichment of the surrounding waters. If the activity is not counteracted by the application of environmental management, the organic matters generated from the activity of aquaculture can cause ecological imbalance in the region, so it can be threaten the sustainability of its business. In recent years, the farming of marine fish using floating net cage system is developing in Awerange Gulf, South Sulawesi, Indonesia. One effort to increase production capacity without increasing the horizontal farming area is applying modification of net farms into stratified double floating net cage (SDFNC) (Putro & Suhartana 2008; Wijayanti et al 2009; Putro 2014; Putro et al 2015). The practice of sustainable aquaculture using SDFNC is considered to be the effective way to reduce impact of fish farming, especially organic enrichment. An efforts to improve the quality of aquatic environments was done by applying the integrated multitrophic aquaculture (IMTA) in order to increase production capacity and operational sustainability. This farming technique is aimed to maintain the carrying capacity of the environment and ecological functions of biota. Shrimp, fish and seaweed have mutual relationship that can work together so this practice can be developed as a form of environmental-friendly polyculture system. Seaweed is a supplier of oxygen through photosynthesis during the day and has the ability to absorb excess nutrients and toxic contaminants in the water. While the plankton-eating fish as a control against excess plankton in the water. Feces of shrimp and fish in the form of soluble organic matters are a source of nutrients that can be used by seaweed and phytoplankton for growth (Putro 2014; Putro et al 2015).

The SDFNC formerly has been applied in the waters of Lake Rawapening, Central Java (Putro & Suhartana 2008; Wijayanti et al 2009), and has succeeded in increasing the production capacity of aquaculture of tilapia (*Oreochromis niloticus*) and *Cyprinus carpio* by almost double compared to conventional cage at the same horizontal extents at Rawapening Lake, Central Java (Putro & Suhartana 2008). The research objective was to develop farming techniques, particularly using floating cages, to increase productivity, and to maintain healthy environment and sustainable aquaculture.

Material and Method. The installation of the SDFNC-Polyculture was done at the aquaculture areas of Gulf Awerange, Barru, South Sulawesi, operated between May-September 2015 in dry season. Geographically it is located between the coordinates 4'0.5'35" South latitude and 199'35"-119'49'16" East longitude.

***Farmed biotas**.* The farm involved three main farmed biota, i.e. rabbitfish (*Siganus* sp.), black tiger shrimp (*Penaeus monodon*), Pacific white shrimp (*Litopenaeus vannamei*) and macro algae (*Euchema cottoni*). *E. cottonii* was cultivated by verticulture method with polyethilene strap of 5 m vertical length at the edge of the cage. The seaweed weight of 250 g was put into a 0.5 inch net bag with 30x50 cm^2 size. Verticulture method is a method of cultivation using ropes, and done by tying the seeds of seaweed in a vertical position (perpendicular) to the ropes are arranged in rows, with verticulture can also take advantage of the water column to limit water transparency. Planting was carried out along the side of the outer SDFNC by 12 lines transversaly from the water surface to a depth of 5 m in all positions on the outside of the net. Total number of rabbitfish cultured was 3600 individuals with initial body weight 10 cm and stocking density of 50 individual m^{-3}, 1200 Pacific white shrimp (100 individuals m^{-3}), 600 PL30 tiger shrimp (50 individuals m^{-3}). The farmed biotas were feed using artificial feed in the form of pellet, with 30% protein content, with the ratio of feed and fish biomass of 2:1.

Abiotic parameters. Abiotic parameters were recorded during the operation, 2 time a week for 4 months (from June to September 2015), including temperature, dissolved oxygen (DO), salinity, pH, phosphate, NO_3, NO_2, NH_4 and water current.

Biotic parameters. The growth of main farmed biotas were recorded. The weight and body length of *Siganus* sp. and *L. vannamei* were calculated every week for 4 months study period. Biomonitoring was carried out by observing the structure of macrobenthic community, especially for mollusks taxa.

Data analysis. Specific growth rate = (SGR) of fish was calculated based on a formula of De Silva & Anderson (1995) as follows:

$$SGR\ (\%) = \frac{Ln\ (W2) - ln\ (W1)}{t} \times 100$$

Where, SGR = specific growth rate (%); W0 = initial body weight at time t days (g); Wt = final body weight at time t days (g); t = time (days).

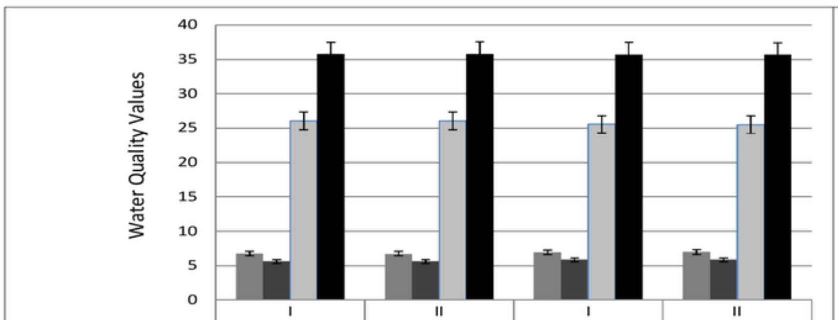
While the daily weight growth rate (RGR = Relative Growth Rate) wass calculated using the following formula:

$$RGR = \frac{Wt - Wo}{Wo x t} \ X\ 100$$

Where, W0 = initial body weight at time t days (g); Wt = final body weight at time t days (g); t = time (days).

In this study the calculation of SGR and RGR were represented for *Siganus* sp. and *L. vannamei*. The diversity of the macrobenthic assemblages was analyzed using Shanon-Wiener index (H') to compare taxon richness between sites and times. Pielou's evenness (e) and dominance (C) indices were used to express equitability (Clarke & Warwick 2001).

Results and Discussion. Based on the data of abiotic parameters at aquaculture areas (Figure 1) over the study period, which exhibited no mark difference over the study period, it can be concluded that the condition of the water wass still within the normal range, both at a depth of 1 m from the surface, 5 m, and 1 m of bottom waters, implying that the area is suitable use for aquaculture activities with relatively strong currents. Dissolved oxygen level wass ranged from 5.59 to 5.84 mg L^{-1}, which means it is still in accordance with water quality standards for aquaculture issued by the Ministry of Environment through the Ministry of the Environment Decree No. 51, 2004.



	SDFNC area		Reference area	
pH	6.77	6.74	6.93	6.97
DO (mg L^{-1})	5.61	5.59	5.83	5.84
Temperature (°C)	26.05	26.08	25.52	25.5
Salinity (ppt)	35.74	35.76	35.71	35.66

Figure 1. The average measurement of water quality parameters taken from 1 m to 5 m depth.

The content of nitrate (NO_3) was still below the water quality standard of Government Regulation for water class II (PP. No. 82 of 2001), which is prescribed limit of 10 mg L^{-1} for fish farming activities. The content of nitrite (NO_2-N) recorded still below the water quality standard of 10 mg L^{-1}, as shown in Figure 2. The content of ammonium ion (NH_4^+ -N), particularly in the measurement of 5 m and 10 m under the surface of the water reaches 0.24 to 0.33 mg L^{-1} (as NH_3). Although ammonia is not required in the determination of water quality class II, however, it is recommended that the water should be free from ammonia content or less than ≤ 0.02 mg L^{-1} for sensitive fish. Ammonium ions derived from NH_3 which is ammonia gas. When NH_3 dissolved in water (H_2O), it will turn into ions NH_4 (ammonium) by releasing HO^- ions.

Furthermore, the content of phosphate (PO_4-P) was still below the measured water quality standard PP. No. 82 of 2001 (class II), which is not to exceed 0.2 mg L^{-1}.

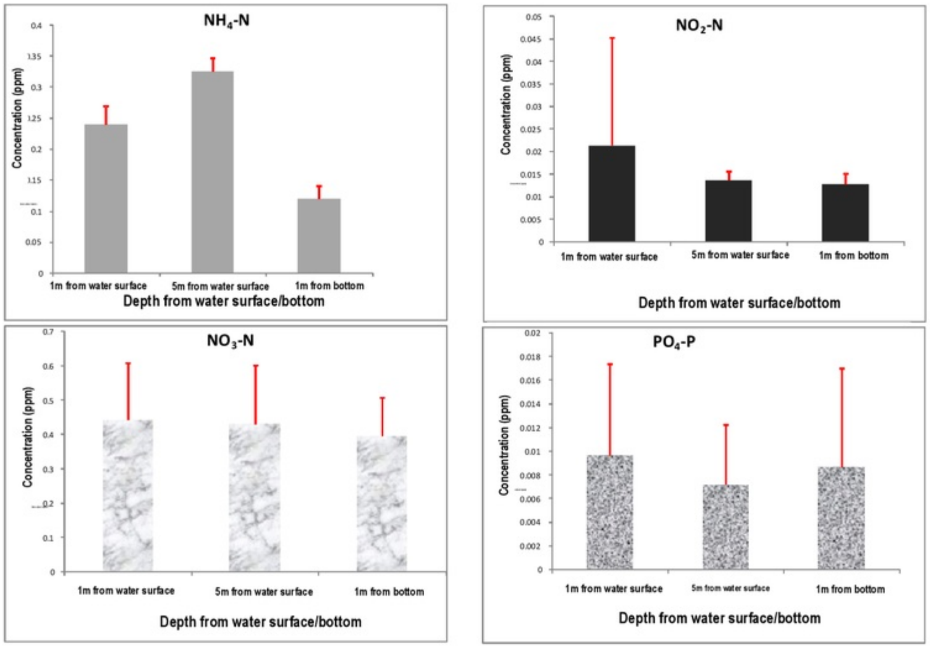


Figure 2. The average measurement of the concentration of organic chemical materials (with standard deviation) in the water at aquaculture area of the Gulf Awerange, South Sulawesi, with different depth levels.

Although growth may be measured in terms of number, weight, volume, energy content, or the amount of a specific component such as protein, this study was limited for growth as weight using expression of specific growth rate (SGR) and relative growth rate (RGR). They were used to measure any change in size or amount of body material, regardless of whether the change is positive or negative, temporary or long-lasting (Schreck & Moyle 1990). In this study, the RGR of *Siganus* sp. and *L. vannamei* were 2.3% and 6.2%, respectively. Meanwhile, the SGR of *Siganus* sp. and *L. vannamei* were 1.05% for 130 days and 1.4% for 120 days, respectively, as shown in Figure 3. The results indicated that the growth of main biotas farmed using SDNFC exhibited faster compared to monoculture farming system, as was reported by Rifai et al (2014) that the SGR for *Siganus* sp. was 0.62% using monoculture floating net cage (6 month rearing period, with initial body weight 13 cm).

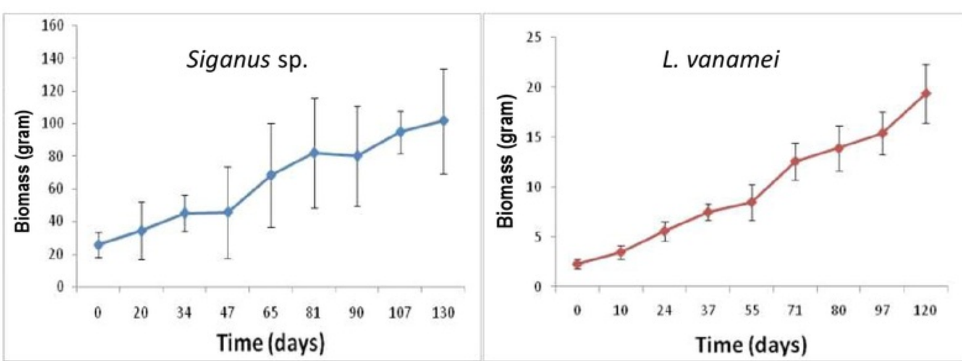


Figure 3. Specific Growth Rate of *Siganus* sp. and *L. vannamei* in the SDNFC.

Biomonitoring was carried out as an assessment of potential environmental disturbance caused by farming activities, comparing the proportion of abundance of macrobenthic molluscs. Overall, there were respectively 180 individuals and 403 individuals recorded at reference and polyculture areas; consisted of 12 species of gastropods and 3 species of bivalves. Based on the sample analyses, *Turritella* sp. was recorded the most dominant at both polyculture and reference areas, followed by *Tellina agilis* (Fam. Tellinidae), *Nassarius castus* (Fam. Nassariidae), and *Anadara* sp. (Fam. Arcidae). The macrobenthic mollusca assemblages indicated more diversed at polyculture areas than those at reference areas, as shown in Figure 4. The macrobenthic mollusks were found as many as 15 species consisting of 14 families and 2 classes (gastropods and bivalves). The mean of macrobenthic abundance at location 1 ($\bar{x}$ = 49.2, SD = 13.9) and location 2 ($\bar{x}$ = 140.67, SD = 8.71) were significantly different (*t*-value = 13.57, *df* = 10). This may be an indication of more food availability for the animals, especially soluble organic matter as they are suspension feeders. This also implies that polyculture areas have more sedimented organic material caused by farming activities as food supply for suspension feeders. It has been suggested that the ability of macrobenthic animals to establish themselves is generally influenced by feeding patterns and food availability (Roth & Wilson 1998).

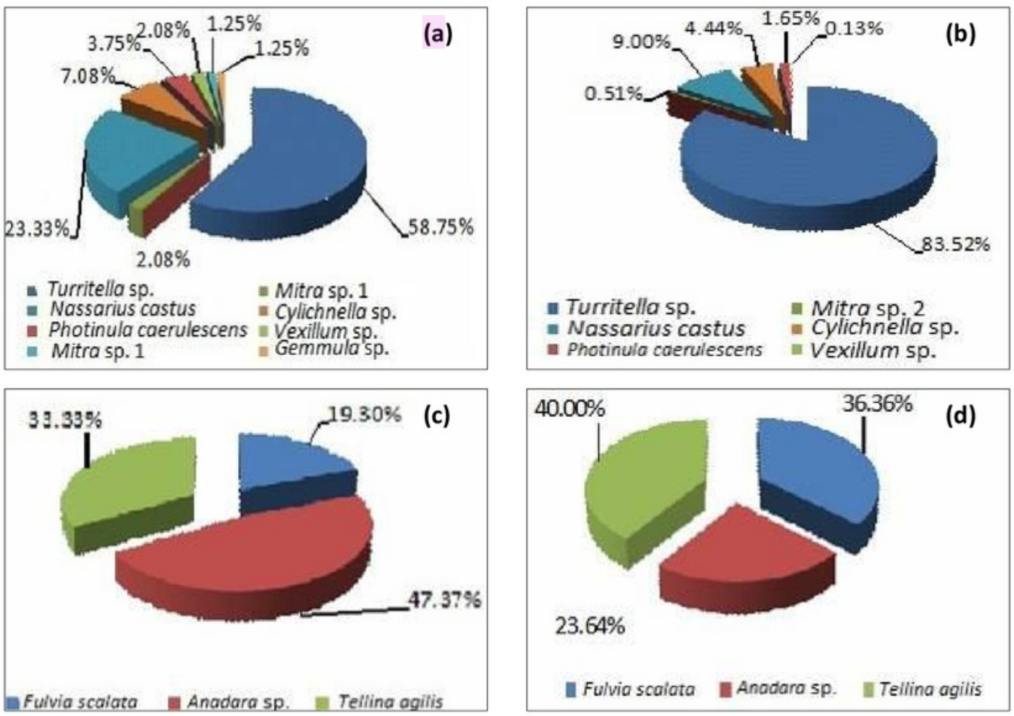


Figure 4. The proportion of abundance of macrobenthic mollusks; (a). Gastropods at polyculture cage area; (b). Gastropods at reference area; (c). Bivalves at polyculture cage area; (d). Bivalves at reference area.

It has been reported that *Turritella* sp. may be used as bioindicator of water pollution, especially trace metal both at fresh water (Heng et al 2004), and marine water (Paul et al 2004) environments. Physico-chemical factors, such as water stability, salinity, sediment characteristics, organic content, dissolved oxygen, particle size and microbiomass, are considered significant factors in influencing the trophic composition of benthic assemblages (Whitlatch 1981; Gaston et al 1998). Grizzle & Morin (1989) emphasized the significant role of tidal currents in food availability for benthic suspension feeders through turbulent diffusion, allowing pelagic production to be available for benthic suspension/filter feeders. Food quality and quantity can thus be a limiting factor for suspension-feeders (Rosenberg & Loo 1983).

The results of diversity index calculation of mollusk community at the study site, as a whole shows that the value of diversity index (H') ranged from 0.78 to 1.88, as shown in Table 1. The highest diversity index value was found in polyculture cage at second sampling time with a value of 1.88, while the lowest diversity index value contained in the reference area first sampling time with a value of 0.78. Meanwhile, the index value of diversity in the first sampling of polyculture cage was 1.32 while in second sampling was 1.88. The index value of diversity in the first sampling of reference area was 0.78, while the second sampling was 1.66.

Table 1

Comparison values of diversity, evenness and dominance indices between polyculture and reference areas

Index	Location			
	Polyculture		*Reference*	
	Sampling I	*Sampling II*	*Sampling I*	*Sampling II*
Diversity (H')	1.32	1.88	0.78	1.16
Evenness (e)	0.63	0.82	0.34	0.56
Dominance (C)	0.39	0.21	0.73	0.49

The results of evenness index value (e) ranged from 0.34 to 0.82 with the lowest evenness index value occured in the reference area at Sampling I (0.34). The index value of evenness at the first sampling of polyculture cage was 0.63 while in second sampling was 0.82. The index value of evenness at the first sampling of reference area was 0.34, while the second sampling was 0.56.

The results of dominance index value (C) in general ranged from 0.21 to 0.73 with the highest dominance index value coming from reference area first sampling with a value of 0.73. Dominance index value on the first sampling in polyculture cage was 0.39 while on the second sampling was 0.21. The index value of dominance on the first sampling in the reference area was 0.73, while the second sampling was 0.49.

The diversity of macrobenthic molluscs is considered low at both sites (H' = 0.78–1.88). Because diversity index emphasizes abundance and number of taxa for its measurement (Putro 2010), the low diversity value may be due to the dominance of certain taxa, as it is expressed by the value of dominance index.

Conclusions. The condition of the waters at the farmed area of Awerange Gulf, Barru, South Sulawesi was within the normal range, thus suitable for aquaculture activities. The growth of main biotas representing by *Siganus* sp. and *L. vannamei* farmed using SDFNC-IMTA exhibited faster compared to monoculture farm, owing to the relatively high values of the RGR (2.3-6.2%) and SGR (1.05-1.4%). The diversity of macrobenthic molluscs was considered low at both sites due to the dominance of certain taxa, as it is expressed by the value of dominance index. The mean of macrobenthic abundance at location 1 ($\bar{x}$ = 49.2, SD = 13.9) and location 2 ($\bar{x}$ = 140.67, SD = 8.71) were significantly different (*t*-value = 13.57, *df* = 10), implying that polyculture areas have more sedimented organic material caused by farming activities as food supply for suspension feeders. It has been suggested that the ability of macrobenthic animals to establish themselves is generally influenced by feeding patterns and food availability. Applications of SDFNC for polyculture system is an alternative way for farming practices to provide an optimum conditions for the farmed organisms and maintain the carrying capacity of the water ecosystem for sustainable aquaculture; however, a routine biomonitoring need to be applied in regular basis in order to anticipate the impact of fish farming.

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