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Correlation between macrobenthic structure (biotic) and water-sediment characteristics (abiotic) adjacent aquaculture areas at Tembelas Island, indonesia

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Abstract. Macrobenthic community play important role in sedimentary habitats as a part of food chain. Their structure may be influenced by environmental characteristic spatially and temporally. The purpose of this study is to access the correlation between macrobenthic structure (biotic) and water-sediment characteristics (abiotic) adjacent aquaculture areas at Tembelas Island, Indonesia. Water and sediments samples were taken twice, where the first and second sampling time were taken in June and October 2016, respectively. Samples were taken in the area of fish farming at coastal area of policulture/IMTA (as Location I), site of 1 km away from fish farming area as a reference site (as Location II), and monoculture sites (as Location III), with three stations for each location. Data of abiotic parameters included the composition of sediment substrate and DO, pH, salinity, temperature, and. Sediment samples were taken using Ekman grab. The organisms were 1 mm -size sieved and fixed using 10% formalin for further analysis, i.e. sorting, preserving, enumerating, identifying, and grouping. The relationship between biotics (macrobentos) and abiotics (physical-chemical factors) was assessed using a non-parametric multivariate procedure (BIOENV). This study found 61 species consisting of 46 families and 5 classes of macrobenthos. The most common classes were member of Mollusca and Polychaeta. Total nitrogen, silt, and clay were the abiotic factors most influencing macrobenthic structure (BIO-ENV; r= 0.46; R^2= 21.16%).

Keywords: macrobenthic structure, relationship, biotic, abiotic, and Tembelas Island

1. Introduction
One of the growing aquaculture sector in Indonesia is in Riau Archipelago. Riau Archipelago is a province that has many islands, one of them is Tembelas Island which is currently used as one of aquaculture locations. Fish farming techniques that exist in Tembelas Island is policulture/IMTA aquaculture (Integrated Multi-Tropic Aquaculture) and monoculture. The activities are potentially have impact on organisms in the aquaculture and marine environment. Macrobenthic is an abundant organism and has a marine waters based life cycle. Ref [1] stated that most of macrobenthic species live as a sedentary lifestyle, intermediate trophic level positions, relatively long life-span and varying responses to changes in environmental stress that make macrobenthic an effective and useful indicator for the assessment of environmental disturbance at coastal ecosystem. Ref [2] emphasised research in

the field of ecology, especially discussion of the spatial and temporal distribution of macrobenthic abundance can be used to determine the level of environmental disturbance over time. Through their spatial and temporal variability, the water ecosystem may be in disturbed or undisturbed situation. Furthermore, Ref [3] stated that analysis of organisms macrobenthic infauna has been applied as one of the main criteria in determining environmental quality for aquaculture management in various countries. Most environmental research have concentrated on severe impacts under and immediately adjacent to fish farming [4]. However, this study differs from previous research, due to the presence of macrobenthic structure correlation and the sedimentary-aquatic characteristics at two different aquaculture, i.e. IMTA aquaculture and monoculture, and at different sampling periods (temporal). The purpose of this study is to access the correlation between macrobenthic structure (biotic) and water-sediment characteristics (abiotic) adjacent aquaculture areas at Tembelas Island, Indonesia.

2. Materials and Methods

This research was conducted on Tembelas Island, Karimun Regency of Riau Archipelago between 103°29'47' - 103°29'90' BT and 0.991°16'63' - 0.989°06'37' LS. The location of the research was divided into three stations at each location sites; fish farming IMTA (Integrated Multi-tropic Aquaculture) site (Location I), Reference site (Location II; ± 1 km away from IMTA aquaculture), and Monoculture site (Location III; ± 3 km away from IMTA aquaculture). The samples of macrobenthic organisms were taken twice at three station at each location. The sediments taken using Ekman grab (10 cm^2) were then fixed in 10% formalin solution. The organisms retained from 1 mm meshsize sieve for each station were then preserved in 70% ethanol solution. Further analysis were sorting, preserving, enumerating, identifying and grouping into the finest taxa resolution (species and genus). The measurement of the physics-chemical water parameters were done three times for each location. The parameters measured in this study were pH, temperature (°C), turbidity, dissolved oxygen (DO), and salinity. Sediment samples analysis at each station comprised sediment composition (sand, silt, clay) and organic content (carbon and nitrogen organic). Data of biotic and abiotic parameters were presented in tables, pie diagrams and histogram with standard deviation. The relationship between biotics (macrobentos) and abiotics (physical-chemical factors) was assessed using a non-parametric multivariate procedure (BIOENV) by PRIMER V.6.1.5. software. It was considered effective to analyze the relationship between select environmental variables (abiotic) and macrobenthic community (biotic) structure. The details of the BIO-ENV algorithm and its suitability for use in analyzing biological/ environmental data interactions are described by Ref [5] and Ref [6].

3. Results

Macrobenthic structure in space and time

The organisms collected from all locations belonged to 5 groups/classes, i.e. 48 molluscs, 13 annelids, 3 arthropods, and 1 ophiuroid, as shown in Table 1. The analysis of macrobenthic organisms at IMTA and monoculture sites indicated a difference in their abundance spatially and temporally, owing to their different in aquaculture technique and sampling time (taken in June and October). Difference in time sampling resulted in differences in water physics-chemical parameter values due to seasonal hydrographical condition.

Table 1. Macrobenthic in Tembelas Island

No.	Groups of Taxa	∑ Spesies Sampling I	∑ Spesies Sampling II
1.	Gastropoda	30 spesies	12 spesies
2.	Bivalvia	13 spesies	5 spesies
3.	Polychaeta	9 spesies	5 spesies
4.	Crustacea	3 spesies	1 spesies
5.	Ophiuroidea	1 spesies	0 spesies

Overall, number of macrobenthic taxa in sampling time II (represent as rainy season) exhibited lower, compared to sampling time I (represent as dry season). In particular, molluscs (gastropods and bivalves) were recorded the highest species found in each location. According to Ref [7], during the rainy season, there are limiting factors for macrobenthic in the presence of anoxic waters and enormous enrichment of nutrients in coastal waters. The presence of changes in sediment substrate (increased sand particles) in sampling II, may cause polychaetes less-able to survive. Ref [8] added that the silty substrate is the preferred habitat of polychaetes to grow and reproduce, since the organic materials on the substrate is used as the main food of the organisms, especially deposit feeders. As shown in Fig 1, the biggest abundance was found in sampling I, there were 55 individuals/grab at IMTA site, 139 individuals/grab at monoculture site, and 398 individuals/grab at reference site, whereas in sampling II there were 38 individuals/grab at IMTA aquaculture site, 48/grab at monoculture site, and 46 individuals/grab at reference sites.

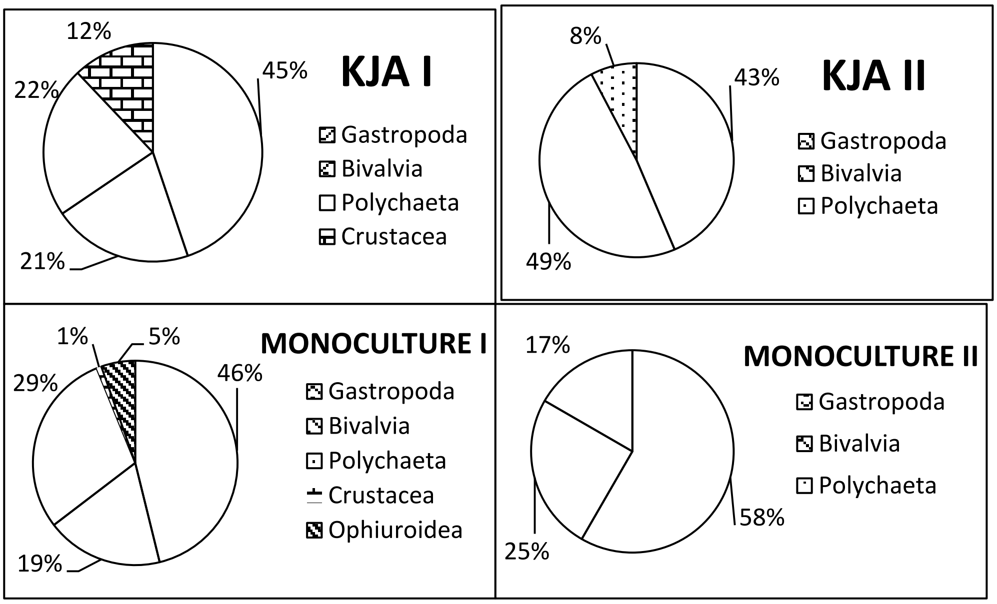
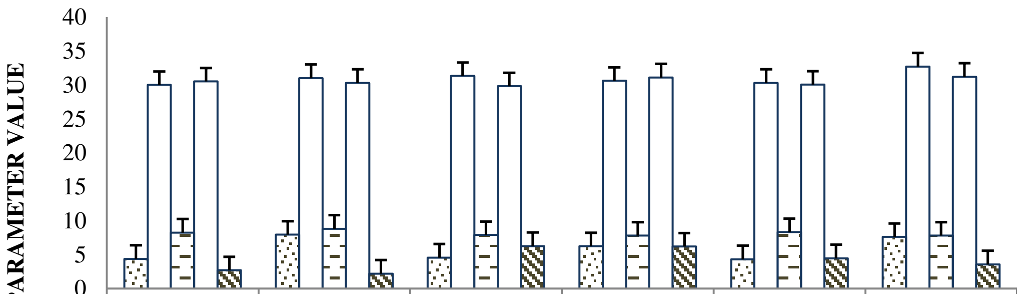


Fig. 1. The differences in proportion makrobenthic groups by location and sampling time.

Member of molluscs found in three locations were *Nassarius* sp and *Anodontia* sp whose presence in almost all sampling sites. *Tellina* sp is also dominant organism of macrobenthic scattered in the farming areas. Ref [9] found that Mollusca is one of the main organisms commonly found inhabiting soft sediment in coastal areas. Infaunal molluscs also usually inhabit sandy and muddy sediments at coastal areas as macrobenthic community. The lowest abundance was crustacean with 3 genus and 1 genus of ophiuroids, which exist only at monoculture site. This may be the site was favorable habitat for those organisms, compared to the farmed sites. According to Ref [10] reference location (as control) is considered as a location that has not been disturbed by human activities, especially the aquaculture of fish cages. The site would have natural water ecosystem that can be used as reference site to be compared to disturbed areas. Ref [11] emphasized that the family Nassariidae of Gastropod generally lives on sandy and silty substrates. Nassaridae is also an organic feeder and suspension feeder that decomposes below on water surface [12]. Furthermore, Ref [13] stated that *Anodontia* sp is often called mud shells due to it inhabits silt areas where its life immersed in mudflat. This is supported by the conditions of sediment at Tembelas Island (all three sampling locations), where the sites were dominated by mud (silt). *Tellina* sp is one of Mollusca that get benefits from the aquaculture activities that undergoes organic enrichment below the water. Ref [14] stated that *Tellina* sp is a deposit feeder organism (immersed in silt) and a suspension feeder at the bottom surface of the sediment. *Nereis* sp, *Capitella* sp, and *Sternaspis* sp were Polychaeta that only inhabit IMTA and monoculture sitesa. According to Ref [15], *Sternaspis* sp is a deposit feeder organism, especially feed on detritus. *Sternaspis* sp usually inhabit smooth silty sediment. Furthermore, Ref [16] stated that the presence of capitellids as deposit feeders are related to sediment characteristics, especially in the silty sediment. Ref [10] stated the physical-chemical changes of an environment can be responded by increasing number of macrobentic species and abundance.

Physical-chemical water parameters
Physical-chemical aquatic parameters measured at IMTA aquaculture, monoculture, and references were dissolved oxygen, salinity, temperature, pH, turbidity, nitrogen content, and carbon, as well as sediment composition on the bottom of aquaculture. The physical and chemical data obtained were pH (7,8 - 8,8), DO (4,32 - 10,93 mg/l), salinity (30 - 32,7$^{o}/_{oo}$), temperature (29,8 - 31,2°C), and turbidity (2,2 – 6,26 NTU).



	KJA I	KJA II	Monoculture I	Monoculture II	Reference I	ReferenceII
DO (mg/l)	4.36	7.93	4.55	6.23	4.32	7.6
Salinity (o/oo)	30	31	31.3	30.6	30.3	32.7
pH	8.24	8.8	7.9	7.8	8.3	7.8
Temperature (oC)	30.5	30.3	29.8	31.1	30.03	31.2
Turbidity (NTU)	2.7	2.2	6.26	6.2	4.47	3.57

Fig. 2. Physical-chemical water parameters by location and sampling time (±SD).

It can be concluded that parameter values of physical-chemical water were recorded within normal range over the study period, as shown in Fig.2.Salinity at all sampling sites was still within a limits of tolerance for farmed and macrobenthic organism life. According to Ref [17], optimum salinity for gastropods and bivalves ranged from 26 to 32 $^{o}/_{oo}$ and from 24-36$^{o}/_{oo}$, respectively. Based on Ref[18], standard of salinity for marine biota is 33-34 ppt, pH range from 7 – 8,5, dissolved oxygen > 5 mg / l, turbidity less than 5 NTU, and temperature range from 28-32^{o}C. The results of DO in time sampling I were under quality threshold, but the value of DO was still within a limits of life and development of macrobenthic and farmed biotas. Furthermore, Ref [19] stated that oxygen depletion may be due to respiration and decomposition of organic substances used by microorganisms. Ref [10] stated that organic matter appeared from aquaculture activities can cause changes in aquatic and sedimentary environments. The continuous accumulation of organic matter can result in reduced oxygen in boundary layer between water and sediment, which ultimately affects changes in composition of infauna macrobenthic organismss.

Sediment properties: sediment grain size and organic content
Sediment properties recorded at the two aquaculture sites and reference site were dominated by silt, i.e. 86,42-97,7% at at IMTA site, 90,4-92.4% at monoculture site and 87,8-92,5% at reference site. The proportion of clay at IMTA, monoculture, and reference sites ranged from 2-3%, 1-7%, and 2-7%, respectively. The proportion of sand at IMTA, monoculture, and reference sites ranged from 0,3-10,58%, 0,6 - 8,6%, and 0,5 - 10,2%, respectively (Fig. 3).

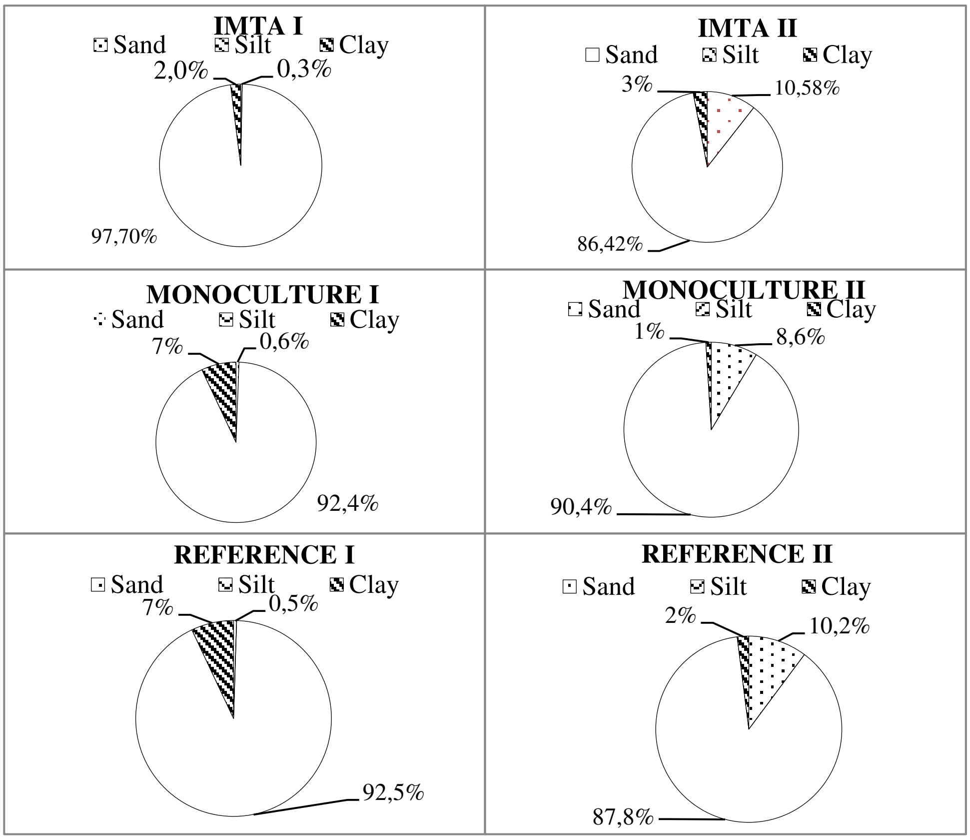
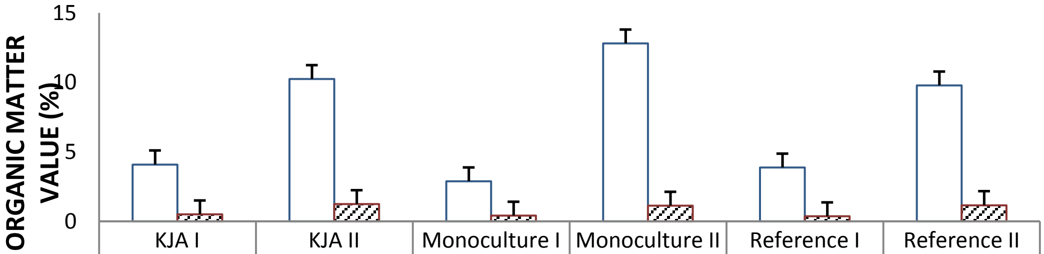


Fig. 3. Composition of sediment grain size by location and sampling time

Ref [20] stated that silty sendiment can be affected by high suspended particles in waters column, resulting in low oxygen levels in the sediment. Type of substrate in the bottom of water column is considerably important for development of macrobenthic community. Sandy substrate may make it easier to macrobenthos move to another place than silty substrate that contains less oxygen. Therefore the organisms live in silty substrate have to adapt under this circumstances. Macrobenthic of bivalves, gastropods, and polychaetes were found in silty sampling sites. According to Ref [21] bivalves and gastropods species have a wider spread, because they are able to adapt to marine habitats with soft or hard sediment textures.

Meanwhile, the composition of organic content at IMTA, monoculture, and reference sites were ranging from 4,09-10,24% C and 0,5-1,24% N, 2,88-12,8% C and 0,41-1,13% N, and 3,87-9,78% C and 0,37-1,16% N, respectively, as shown in Fig. 4.



	KJA I	KJA II	Monoculture I	Monoculture II	Reference I	Reference II
Carbon (C)	4.09	10.24	2.88	12.8	3.87	9.78
Nitrogen (N)	0.5	1.24	0.41	1.13	0.37	1.16

Fig. 4. Proportion of organic matter in the form of Carbon and Nitrogen by location and sampling time (±SD).

Assessment of relationship between abiotic and biotic factors
The results of analysis BIO-ENV, as shown in Table 2, explained that total percent of nitrogen, silt, and clay were the abiotic factors most influencing macrobenthic structure (BIO-ENV; r= 0.46; R^2= 21.16%). This may imply that nitrogen in sediment of marine waters is a basic requirement that affects in growth and reproductive control of macrobenthic organisms. Therefore, the sedimentary substrate greatly determines abundance and distribution of macrobenthic community. The high organic matter (Carbon and Nitrogen) at farmed sites, especially in sampling time II (as rainy season) may be generated from accumulation of organic matter (nutrient enrichment) from the residual feed and residual feces during farming activities in sediments and water column. Ref [22] stated that sediments that have high organic matter can support an abundance of infauna dominated by deposit feeders. Furthermore, Ref [23] stated that source of organic nitrogen in water column is mainly produced from decay process of living things that have died, while anthropogenic source is derived from fishery and industrial activities.

Table 2. The relationship between abiotic and biotic factors using BIO-ENV software PRIMER V.6.1.5.

No	Correlation Coefficient (r)	Determination Coefficient (R^2)	Variables	Number of Variable
1.	0,46	21,16%	7,9,10	3
2.	0,46	21,16%	8, 9, 10	3
3.	0,44	19,36%	9, 10	2
4.	0,44	19,36%	7, 9	2
5.	0,42	17,64%	7, 8, 9, 10	4
6.	0,41	16,81%	6, 9, 10	3
7.	0,40	16%	7, 8, 9	3
8.	0,40	16%	3, 9, 10	3

Table footnote: 1) DO, 2) Salinity, 3) pH, 4) Temperature, 5) Turbidity, 6) %C, 7) %N , 8) Sand, 9) Silt, 10) Clay,

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