21 Spatial and temporal patterns of macrozoobenthic community inhabiting sediments under tropical fish farming

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Spatial and temporal patterns of macrozoobenthic community inhabiting sediments under tropical fish farming

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Abstract. Macrozoobenthic animals is one of biota that may be used to assess the impact of the activities. They inhabit sediment of water ecosystem and may respond vary at different spatio-temporal scales. The purpose of this study is to study spatial and temporal patterns of macrozoobenthic community under fish farming activities at coastal area of Tembelas Island, Kepulauan Riau Province, Indonesia. The macrozoobenthic assemblages were assessedat three sampling locations, i.e. policulture [IMTA], monoculture and reference sites. Each sampling location consisted of three stations with three replicates for each station. The data obtained were analyzed using PRIMER software V.6.1.5. to compare number of taxa (S), Shanon-Wiener diversity index (H'), and Pielou's evenness index (e) and K-dominance cumulative curves between sites and times. The results showed that diversity index at fish farming locations (IMTA and monoculture) exhibited lower than those at reference site, between 1.58 – 2.19 and between 1.99-2.84, respectively. However, diversity at all locations were considered moderate diverse ecosystem. Meanwhile, Pielou's evenness indexbetween locations and sampling time showed no majordifference, ranging between 0.96-0.98. Based on K-dominance curves, P3T2 station curve was positioned on the top among other curves, implying certain taxa has dominated the assemblages, i.e. *Nassarius* sp. (Gastropod).

Keywords: aquaculture, macrozoobenthic community, organic enrichment, diversity index, and evenness index

1. Introduction

Over the last ten years, fish farming in Indonesia has developed from monoculture to polyculture system [1]. Both activities may produce organic waste in the form of organic nitrogen, phosphor and ammonia that may spread from tens to hundreds of meters from fish farming area, resulting disturbance and contamination in the aquaculture environment and surrounding areas [2].

The impact of fish farming can be reduced through modification of farming practice to growing up more than one species in the same areas (integrated aquaculture). In line with the time, Integreted Multi Trophic Aquaculture (IMTA) has been introduced to produce several farmed biotas at the same

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time at the same areas [3], thus reduce the environmental impact [4]. The concept of IMTA is the practice of aquaculture which involves a mutualistic relationship between farmed organisms from low trophic level, i.e. suspension feeder organisms to a higher trophic level organism i.e. carnivore fish [5,6]. Polyculture and multitropic aquaculture systems have been shown to create an ecosystem within a balanced area [7] so that IMTA applications contribute to the sustainability of aquaculture [6]. Studies on IMTA-based seaweed cultivation have been conducted. However, generally the study was conducted at subtropical areas [3]. The results of the Troell [8] study in Metri Bay, Chilli showed that *Gracilaria* sp. cultivated at a distance of 10 m from floating net cages of salmon had a 40% increase in biomass. According to Troell *et al* [22] seaweed, has a key role as a biofilter and an economically valuable biomass producer, where fish farming wastes released as unfed pellet and fish feces and urine can be a source of nutrients that are very useful for seaweed growth.

Macrozoobenthic community inhabiting sediment under water ecosystem is generally very sensitive to changes in the aquatic environment, both spatial and temporal. Therefore, their distribution pattern, diversity and dominant are often used as biological indicators because of their way of life, body size, and different tolerance ranges among species within aquatic environments. The use of indicator organisms to assess water quality is very useful for routine biomonitoring and the status of water ecosystem. Thus, the taxa of indicators can be use as a complementarypart or strengthen the assessment of water quality based on physical and chemical parameters [9]. Consequently, further research is urgently needed to determine the quality of aquaculture fisheries using macrozoobenthic community.

2. Research Methods

The sampling sites was located at Tembelas Island, Kepulauan Riau, Indonesia. Three sampling locations were assessed with three stations and three replicates for each location, i.e. floating net cage of monoculture, floating net cage of IMTA, and reference area. The base sediments taken from three locations using Eckman Grab then the sample was introduced into a plastic bottle containing 4% of formalin solution. Samples of animal macrozoobenthic were treated by rinsing, sorting and preservation in 70% of ethanol solution. Macrozoobenthic identification is performed using identification books [23] after that calculation of the amount of types, tabulation and calculation was conducted. The diversity of the macrozoobenthic assemblages was analysed using). *Shanon-Wiener* index (H'), *Evenness* (e) index was used to express similarity [24] and K-Dominance Curve using PRIMER software V.6.1.5. k-Dominance curves belong to this class of techniques, and have been quite widely used in the context of environmental assessment [25].

The formula of *Shanon-Wiener* index (H') is as follows:

$$H' = -\sum_{i=1}^{s}\left(p_i\right)\left(\log_2 p_i\right) \tag{1}$$

Specification:

S   = number of species
Pi   = proportion of the total sample of i-th species = ni / N
ni = number of individuals of i-th species
N   = total number of individuals of all species

H' value normally will not be more than 5 (five). In general, the greater number of species in the community, then the value of the index H' will be higher as well. Meanwhile, *Evenness* (e) index is calculated as follows:

$$e = \frac{H'}{\ln S} \tag{2}$$

Specification:

H'   = index of species diversity (species) *Shanon- Wiener*
Ln   = exponential logarithm
S   = number of species (types).

The higher the value of e, the higher similarity degree between several types of communities compared will be.

3. Results and Discussion

3.1. physical-chemical factors at tembelas island

Table 1. Result of measurement of water quality parameters.

	DO (mg/l)	Salinity (ppt)	pH	temperature (oC)	turbidity	%C	%N	Smooth sand	Silt	Clay
Poluculture I	4.30	30.00	8.50	30.57	27.67	4.09	0.5	0.3	97.7	2
Polyculture II	7.41	31.00	7.67	30.47	25.00	15.24	1.13	10.58	86.42	3
Monoculture I	4.61	31.00	7.63	29.90	56.00	2.88	0.41	0.6	92.4	7
Monoculture II	6.33	30.67	7.73	31.23	59.33	12.08	1.13	8.6	90.4	1
Reference I	4.50	30.67	8.30	30.13	26.00	3.87	0.37	0.5	0.5	7
Reference II	6.13	32.67	7.60	31.60	45.00	9.78	1.16	10.2	87.8	2

The water quality in the coastal island ofTembelas Riau Islands Province in the three research sites (polyculture, monoculture, reference), among others obtained DO (4,30-7,41) (table 1). The oxygen level (DO) indicates that the waters in the first and second sampling are still quite good. The optimum oxygen content (DO) for benthic animals is> 4.0 mg / l [14]. Decreasing dissolved oxygen can cause serious problems for macrozoobenthos animal life, the reduction of oxygen in waters is usually associated with high organic material entering the water [15].

The salinity range in each of the research areas for the first and second samples had a fairly high salinity level of 30.00-32.67 but was still tolerable by benthos animals. The ideal salinity for macrobenthos biota growth is 26 ‰ - 37 ‰ [19]. pH on the coast ofTembelas island in the three research sites is still normal between 7.60 to 8.50 and allows for benthos animals to live. According Efendi[16], the pH range that can still be tolerated benthos animals is 6.5-8.5. Temperatures obtained at the study sites in both the first and second samples were 29.90-31.60 ^{0}C. the temperature value at the study site is good for macrobenthos life and is in the normal range, this is in accordance with the Odum[11] statement that is the ideal temperature for growth and reproduction of gastropod is generally 25-32^{0}C.

Based on the decree of ministry for environment year 2004, the standard of turbidity for marine biota is less than 5 NTU. The lowest turbidity or turbidity values are in the location of Monoculture either at the time of the first sampling or the second sampling. High turbidity levels will disrupt the penetration of light into the water, consequently can interfere with the process of photosynthesis and affect the decrease in dissolved oxygen content, thus decreasing the productivity of the water [17].

The nitrogen content in the first sampling averaged 0.37-0.5, while the second sampling averaged 1.13-1.16. The first and second sampling has a long time lag so that organic matter may accumulate in the area. According to Effendi [16], the source of organic nitrogen in the waters comes from the decay of living things that have died while the anthropogenic source is derived from fishery activities.

Be aware of sediment data obtained in polyculture cultivation area, monoculture and reference area, third location there are three substrate granular composition ie smooth sand, silt and clay. The three research sites are dominated by silt / mud. The highest value of silt was found at the polyculture site on the first sample of 97.7%. However, silt peresntasi value at all three locations do not have differences too high. The highest smooth sand value was found at the polyculture site on the second sampling 10.58%. The highest clay value was found at the monoculture site on the first sample and the reference area on the first sample. This is due to the sedimentation process or the substrate influenced by the velocity of the current in the area [18].

3.2. Macrozoobenthic abundance based on locations

Based on the identification results both in the first and second sampling on the floating net cage area of IMTA system, the floating net of the monoculture system and the reference area is Gastropoda class

there are 48 species from 27 families. Bivalvia class there are 18 species from 10 families. Class Polychaeta there are 13 species from 6 families. Crustacean class there are 4 species from 3 families and Ophiuridae class there is 1 species from 1 family (Figure 1).

From the results of identification, is a family of gastropods and bivalves class with a fairly high distribution found in all three locations.This is because Gastropods can live and thrive on a wide variety of sedimentary structures and can adapt to waters dominated by mud and sand substrate types.
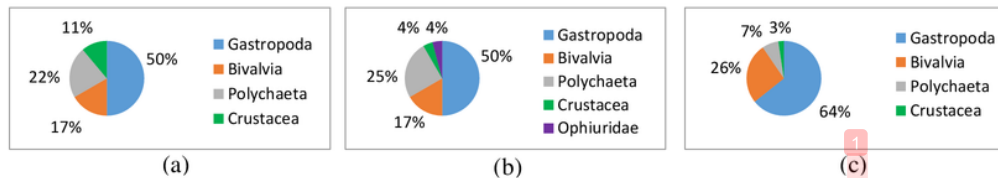

Figure 1. Proportion of macrozoobenthic abundance (a) on floating net cage of monoculture (b) on floating net cage of IMTA (c) on reference area

3.3. Diversity index

The value of the Shanon-Wiener (H ') diversity index taken from Wilhm and Dorris[10] is the value of diversity considered low if H' <1, considered moderate when 1 <H '<3, and is considered high if H'> 3. The index values in the three locations both at the first and second sampling were moderate. This indicates that there has been pollution and degradation of water quality. Ulum [20] states that The better the aquatic environment, then the index value of biota diversity will be higher, and vice versa. The index of species diversity will decrease as the condition or quality of the aquatic environment decreases.

The index value of diversity in the first sampling was highest in the reference area with a value of 2.84 while the lowest was in the polyculture location with a value of 1.98. The index value on the second highest sampling is the monoculture location with a value of 2.19, while the lowest index value is at the polyculture location with the value of 1.58 (figure 2). Sampling is based on different time and has a long enough pause that the first time and the second time shows the index value of diversity (H ') of macrobenthos animals is moderate. The low value of the diversity index is thought to be due to an inability to compete for feeding with more adaptive biota, whereas high biodiversity values are thought to be related to the ability of a number of genera to tolerate environmental parameters [11]. The diversity of the genus in a community is judged to be low if its distribution is uneven, where certain species are found in abundant quantities but there are certain genera found only slightly.

	Monoculture	Polyculture	Reference
Time 1	2.19	1.98	2.84
Time 2	2.19	1.58	1.99
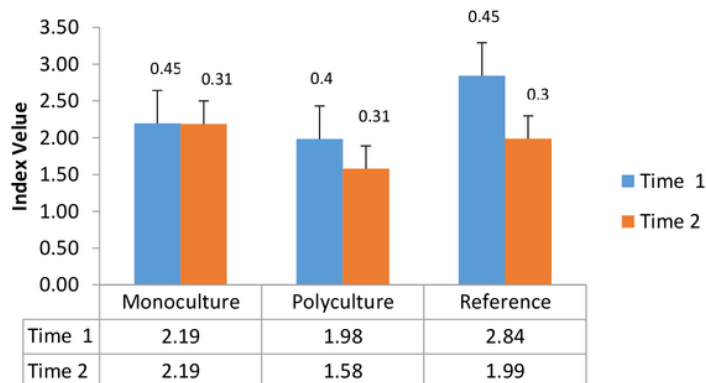
Figure 2. The average of diversity index, comparing sampling locations and sampling time.

*3.4 Evenness Index*

The Pielou's evenness value (e) of the results of the research on the first sampling in monoculture was 0.97, while the second sampling was 0.98. The index value on polyculture in the first sampling was 0.98, while at the time of the second taking was 0.96. The first sampling in the reference area was 0.96, while at the time of the second sampling was 0.98 (figure 3).

	Monoculture	Polyculture	Reference
Time 1	0.97	0.98	0.96
Time 2	0.98	0.96	0.98
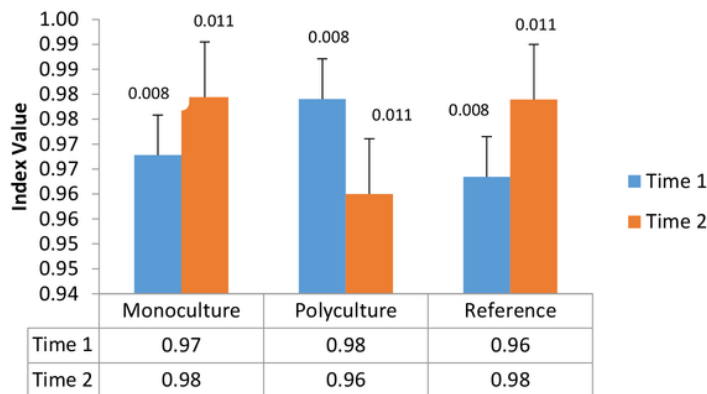
Figure 3. The average of evenness index, comparing sampling locations and sampling time.

The Pielou's evenness index value was 0.98 in the second sampling monoculture, the first sampling polyculture and the reference area on the second sample. The lowest index value was found in polyculcur at the time of the second sample and the reference area at the time of the first sampling was 0.96. Odum [11] stated that if uniformity is categorized as high, then it shows a large species similarity, meaning the abundance of each particular species is smaller. Brower [12], the uniformity index is considered small when e <0.4, considered moderate when 0.4 <e <0.6 and is considered high when e <0.6. The index values of the three sites, both at the first and second sampling, have a high uniformity index value, indicating that the presence of each type of biota in the water is in an even condition [13].
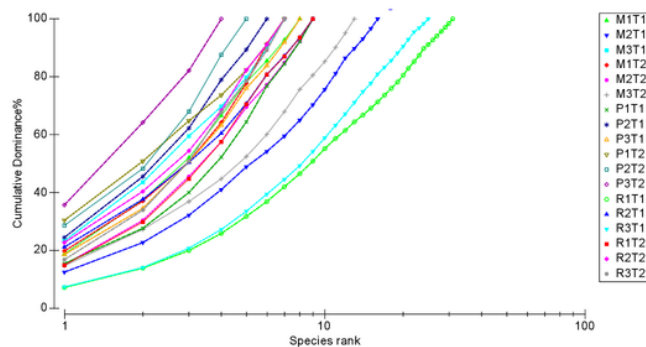
Information:
M1T1 : First monoculture, first sampling time; M2T1 : Second monoculture, first sampling time; M3T1 : Third monoculture, first sampling time; M1T2 : First monoculture, second sampling time; M2T2 : second monoculture, second sampling time; M3T2 : Third monoculture, second sampling time; P1T1 : First polyculture, first sampling time; P2T1 : second polyculture, first sampling time; P3T1 : Third polyculture, first sampling time; P1T2 : First polyculture, second sampling time; P2T2 : Second polyculture, second sampling time; P3T2 : Third polyculture, second sampling time; R1T1 :First reference area, first sampling time; R2T1 : Second reference area, first sampling time; R3T1 : Third reference area, first sampling time; R1T2 : First reference area, second sampling time; R2T2 : Second reference area, second sampling time; R3T2 : Third reference area, second sampling time
Figure 4. The K-Dominant Cumulative Curve Projected for Each Station.

3.5 Macrozoobenthic K-Dominance Curve
K-dominance cumulative curves analyzed using PRIMER software V.6.1.5 [27], show that P3T2 station curves are at the top (Figure 4). This shows that the P3T2 station has the lowest diversity and evenness among other stations, implying certain taxa has dominated the assemblages, i.e. *Nassarius* sp. (Gastropod). Meanwhile, the curves of R1T1 and R3T1 are on the lowest curve, indicating the highest diversity and similarity of species among other stations [26].

4. Conclusion
Based on the research result, it is concluded that the quality of waters in the aquaculture area is still considered good from the diversity index and the uniformity index of macrozoobenthicassemblages.K-dominance cumulative curves is considered sensitive in detecting the changes of macrozoobenthic assemblages. *Nassarius* sp. (Gastropod) may be used as an bioindicator of environmental disturbance, especially organic enrichment caused by fish farming activities.

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