Seasonal variation of bivalve diversity in seagrass ecosystem of Labakkang coastal water, Pangkep, South Sulawesi, Indonesia

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Abstract. One of the fisheries resources in the coastal area of Labakkang, Pangkep Regency, is bivalve which mostly found in seagrass ecosystem. A study on bivalves of seagrass ecosystem was conducted based on seasons, July to September 2013 (dry season) and January to March (rainy season). It was aimed at knowing the bivalve diversity in relation with seasons. The study used a quadratic transect method from the coastal line seawards to the end of seagrass population. Results show that there were found 323 individuals of 17 species in dry season and 216 individuals of 14 species in rainy season. *Anadara* sp. (Arcidae), *Marcia hiantina* and *Anomalodiscus squamosus* (Veneridae) are dominated species in that area. Ecological index in either dry or rainy seasons showed that species diversity was moderate (1.832-2.235) that the ecosystem has got pressures, while the eveness index was even enough and there was no species dominance despite some species found in high abundance. Environmental parameters could still be tolerated by the bivalves, and other marine biota.
Key Words: species diversity, bivalve, season, environmental parameters.

Introduction. Seagrass ecosystem is one of the productive ecosystems in the coastal area playing important roles in various marine life. It physically acts as abrasion barrier and ecologically as shelter for various biota, provides various types of food and becomes nursery ground for marine biota, such as crustacea, polychaete, echinoderm, mollusc (bivalves and gastropod) and fish, both juveniles and adults (Coles et al 1993; Belgacem et al 2013). One of the fauna groups generally found abundant in the seagrass bed is mollusc, living either as epifauna or infauna/bivalves (buried in the sediment). In food chain, epifauna is the component utilizing the epiphyte biomass on the seagrass leaves, while infauna is the component feeding on the litters on the sediment surface (Printrakoon et al 2008; Barros & Rocha-Barreira 2013). According to Klumpp et al (1992), mollusc is a very important component in the seagrass ecosystem either in relation with the biomass or its role in energy flow. As many as 20–60% of the epiphyte biomass in the seagrass bed are used by the epiphytes with gastropod dominace.

Pangkep Regency possesses more extensive marine area (11,464.44 km^2) than the terrestrial (898.29 km^2) with a ratio of 1:13. Major coastal ecosystems of this regency are coral reefs, mangroves, and seagrass beds. One of the seagrass ecosystems in the coastal area of Pangkep Regency is located in Labakkang. Since there are high human activities (anthropogenic) in the area, such as industrial development, harbor, residence, and environmental unfriendly fishing activities, such as bombing and poisoning, can cause changes in the quality of aquatic environment, such as physico-chemical parameters of the waters, that could affect the occurrence of the seagrass ecosystem. Decline or loss of the ecological roles of the seagrass ecosystem results in biodiversity and fisheries productivity decline. According to Anyona et al (2014), anthropogenic activities have negative impact on changes in physico-chemical parameters of the waters and the occurrence of macroinvertebrates and other aquatic biota.

Coastal villagers of Labakkang largely utilize the seagrass bed to search for molluscs, particularly bivalves, fishing, portunid crabs and others. In general, bivalves have direct or indirect important value. They are used as food or income source. Information on bivalve diversity in this area is still few or even none, and therefore, this study was carried out. This study was aimed at knowing the bivalve diversity and several environmental parameters based upon season in seagrass ecosystem of Labakkang coastal area. The results are expected to be able to use as basic information for marine resources utilization and development efforts, particularly bivalves in the area.

Material and Method. This study was done in the coastal area of Labakkang District, Pangkep Regency, covering Borimasunggu, Pundata Baji, and Desa Bontomanai, located along the coast (Figure 1). It was conducted in July to September 2013 (dry season) and January to March, 2014 (rainy season). The analyses of water quality, sediment/substrate and molluscs were carried out in the laboratoy of Chemical Oceanography and Marine Biology, Hasannuddin University, Makassar.

Figure 1. Map of research sites and sampling stations.

Observation station. Observation station characteristics are presented in Table 1.

Table 1

The characteristics of study sites

Station	*Long. & Lat.*	*Characteristics*
Borimasunggu village (Station A)	04^{o}47'32,86'' LS 119^{o}29'30,07' BT	Seagrass bed habitat bordering with Tonasa cement harbor, small river, mangrove forest, and fish ponds
Pundata Baji village (Station B)	04^{o}46'34,54" LS 119^{o}29'27,66" BT	Seagrass bed habitat bordering with residence, river, crossing harbor to surrounding islands, mangrove forest and fish pond
Bontomanai village (Station C)	04^{o}44'36,01" LS 119^{o}28'57,77" BT	Seagrass bed habitat bordering with mangrove forest and fish pond, small river

Sampling procedure and laboratory. Sampling was done by setting the transect line seawards perpendicular to the coastal line (up to no seagrass found), each of 20 m long was put a 1 m x 1 m quadrat, and all molluscs in the transect were collected and preserved in 10% formaldehyde for laboratory identification. The identification followed Macdonald & Co (1982), Carpenter & Niem 1998), and Dharma (2005). To support the field data, several oceanographic physical and chemical parameters were also measured, i.e. water pH, salinity, temperature, turbidity and current speed. All measurements were carried *in situ*. Dissolved oxygen, pH, temperature, and salinity measurements used YSI 650MDS-typed DO-meter, and current speed was gained using a current meter, while turbidity and sediment were analyzed in the laboratory of oceanographic chemistry, UNHAS.

Data analysis. Data of mollusc density were tabulated in MS excel format processed in PRIMER software. The nMDS Plot was based on Bray-Curtis matrix equation to reveal the group compositions in two-dimensional space. The close points indicate similarity in species composition and the wide plot distance reflects the extent of species variation in the group. These were then tested with ANOSIM to obtain the difference coefficient. To know which genera cause the difference between the two communities, SIMPER analysis was applied. Also, genus diversity index Shannon-Wiener index (H), eveness index or Pielou index (J) and richness index or Margalef index (d) were assessed. All these analyses used V.6.1.6 PRIMER (Plymouth Routines In Multivariate Ecological Research) program (Clarke & Warwick 2001; Clarke & Gorley 2006; Fredriksen et al 2010). The relationship between environmental parameters and mollusc density was analyzed using multiple regression analysis with SPSS 18 software.

Results and Discussion

Aquatic environmental parameters. Organism abundance in the waters is highly influenced by surrounding environmental factors. Garg et al (2009) found that benthic organisms (molluscs) occurrence was affected by various aquatic environmental factors, such as temperature, salinity, current, pH, water depth, and bottom substrate. Aquatic environmental parameter measurements are presented in Table 2.

Table 2
Mean value of environmental parameters and bottom substrate types in Labakkang coastal waters

Parameter	*Dry season*			*Rainy season*		
	A	*B*	*C*	*A*	*B*	*C*
Temperature (°C)	31.49±0.25	31.12±0.72	31.33±0.24	28.85±0.62	29.56±0.56	29.65±0.20
Salinity (‰)	34.21±0.52	33.87±0.23	33.49±0.33	26.89±0.27	27.59±0.09	28.04±1.07
pH	8.08±0.19	8.29±0.08	8.30±0.027	7.19±0.09	7.23±0.05	7.28±0.04
Dissolved oxygen (mg L^{-1})	5.27±0.59	5.90±0.42	6.03±0.13	4.06±0.22	4.17±0.39	3.80±0.33
Current (m s^{-1})	0.053±0.06	0.043±0.04	0.050±0.01	0.073±0.01	0.059±0.01	0.078±0.004
Turbidity (NTU)	19.15±11.03	29.53±9.58	20.89±3.76	85.71±23.99	49.30±40.09	28.48±15.88
Water depth (m)	64.00±11.36	77.67±3.51	62.67±4.51	69.00±12.17	85.00±3.61	69.67±2.52
Clay (%)	6.00±4.00	6.00±4.00	9.33±1.16	2.67±1.16	3.33±2.31	6.67±2.31
Ash (%)	12.67±6.11	15.33±5.03	11.33±1.16	16.67±3.06	21.00±5.57	17.33±3.06
Sand (%)	81.33±2.31	78,67±1.16	79.33±1.16	80.67±2.31	75.67±5.69	76.00±3.46
Seagrass density (stands m^{-2})	26.72±32.05	39.95±27.97	54.17±33.00	22.33±26.87	29.67±23.11	36.82±30.97

Based on the environmental parameters, temperature range of 28.853–31.49°C belongs to normal seawater water quality standard for marine biota and could be tolerated by molluscs. Water temperature directly affects animal activities, such as growth or their metabolisms and even can cause mortality. Salinity ranged from 26.89 to 34.213 ‰ and pH from 7.193 to 8.300 belonging to optimum condition for aquatic biota. According to Riniatsih & Widianingsih (2007), salinity range of 5–35 ‰ and pH > 5 and < 9 are optimum for the survival of bivalves. Dissolved oxygen ranging from 3.80–6.03 mg L^{-1} was still in the tolerance limit of marine biota, > 2 and > 5 mg L^{-1} (EPA 2002). Current speed ranged from 0.043 to 0.078 m sec^{-1} categorized as slow and current condition is highly related with bottom substrate type as habitats of various biota, particularly molluscs. In general substrate particle size affects the density and the composition of molluscs, in which the strong current habitat has bigger particles as sand or rubbles since smaller particles are drifted by current and wave, and inversely, fine particles will suspend and become substrate in the weak current area. The substrate types found in the coastal area of Labakkang are in general argillaceous sand and this type sufficiently supports the mollusc life.

Water depth ranged from 62.667-85.000 m and the deeper the water the smaller the bivalve density was found. Turbidity ranged from 19.147–85.710 NTU, and this value has exceeded the recommended limit for aquatic life is 8 NTU (Water Management Branch 1981). Patang (2009) found the turbidity of 32.27 NTU in the coastal waters of Labakang. This difference could result from different measurement time and station. This high turbidity is related with easily agitated argillacious sand substrate condition if water moverment occurs because the area is located in the coast and intertidal. Basically, environmental parameters of Labakkang coastal waters show a normal range value and suitable for aquatic biota in spite of slight difference among stations due to various activities, such as harbor (Tonasa cement and crossing to the islands), river flow and residence.

Regression analysis revealed that mean bivalve density was positively correlated with percent clay and ash and negatively correlated with water depth and turbidity, while other parameters did not highly contribute to the bivalve density. The relationship between the bivalve density and the environmental parameters follows the equation below:

$$\text{Bivalve density (Y)} = 3.147 - 0.033*\text{depth} - 0.008*\text{turbidity} + 0.056*\text{clay} + 0.043*\text{ash} \quad (R^2 = 0.776)$$

Looking at the equation above, mean bivalve density tends to decline with depth and turbidity increment, and inversely, incline with clay and ash content increment. The determination coefficient (R^2 = 0.776) means that nearly 77.6% of mean bivalve density variability in the study site are described by the variability of 4 environmental parameters, depth, turbidity, percent clay and ash. Under the assumption of constant turbidity, percent clay and ash, the increase in each 1 m depth makes the mean bivalve density decline as many as 0.033 ind/m^2. This finding is in agreement with Belgacem et al (2013) that species richness of the mollusc is negatively correlated with water depth. Increase in percent clay as many as 10% causes mean bivalve density increment of 0.056 ind/m^2. In general, the bivalves live in finer substrate to ease burying themselves in it. Sediment particle size also affects the organic content in the sediment, in which clay and ash sediments with finer textures have high organic content. Bottom substrate is attatching, crawling and burying site of the molluscs, in which bivalves are found more in muddy sandy substrate (finer texture), while gastropods in sandy bottom (coarser texture) (Beasley et al 2005).

Species composition and bivalve density. Species identification of the molluscs from 3 sampling stations in dry season and rainy season are presented in Table 3 and Figures 2 and 3.

Table 3

Species composition and density percentage (ind/m^2) bivalves by season

No	Family	Species	Dry season			Rainy season		
			Density (ind./m^2)	Σ Ind.	%	Density (ind./m^2)	Σ Ind.	%
1	*Arcidae*	*Anadara antiquata*	4.67	42	13.00	4.45	40	18.52
2		*Anadara granosa*	0.89	8	2.48	0.22	2	0.93
3		*Anadara gubernaculums*	3.67	33	10.22	1.11	10	4.63
4		*Anadara inaequivalvis*	4.45	40	12.39	5.23	47	21.76
5	Pharidae	*Siliqua winteriana*	1.44	13	4.02	0.33	3	1.39
6	Mactridae	*Mactra grandis*	0.44	4	1.24	0	0	0
7	Mytilidae	*Mytilus edulis*	0	0	0	1.89	17	7.87
8	Pinnidae	*Atrina vexillum*	0.56	5	1.55	0	0	0
9		*Pinna bicolor*	0.33	3	0.93	0	0	0
10		*Pinna muricata*	0.33	3	0.93	0	0	0
11	Psammobiidae	*Gari elongata*	0	0	0	0.56	5	2.32
12	Semelidae	*Semele casta*	0	0	0	0.78	7	3.24
13	Tellinidae	*Leporimetis ephippium*	0.33	3	0.93	0	0	0
14		*Tellina perplexa*	0.67	6	1.86	0.33	3	1.39
15		*Tellina timorensis*	0.33	3	0.93	0.11	1	0.46
16	Veneridae	*Anomalodiscus squamosus*	3.11	28	8.67	1.44	13	6.02
17		*Dosinia subrosa*	0.22	2	0.62	0	0	0
18		*Gafrarium pectinatum*	1.67	15	4.64	0	0	0
19		*Marcia hiantina*	11.11	100	30.96	6.89	62	28.71
20		*Pitar citrinus*	0	0	0	0.22	2	0.93
21		*Placamen chloroticum*	1.67	15	4.65	0.44	4	1.85
	Total		-	323	100	-	216	100
	No. of species			17			14	

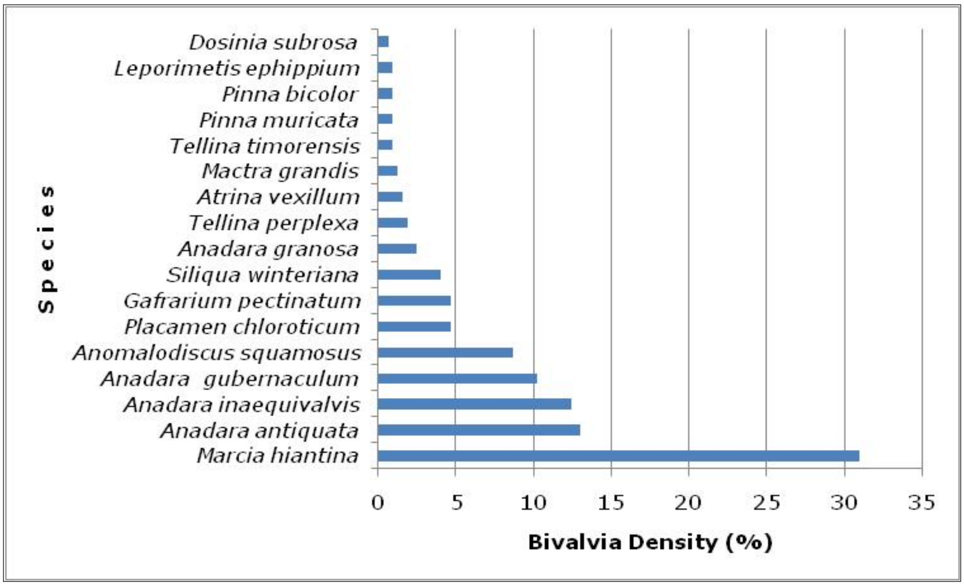

Figure 2. Percentage of bivalve density in dry season.

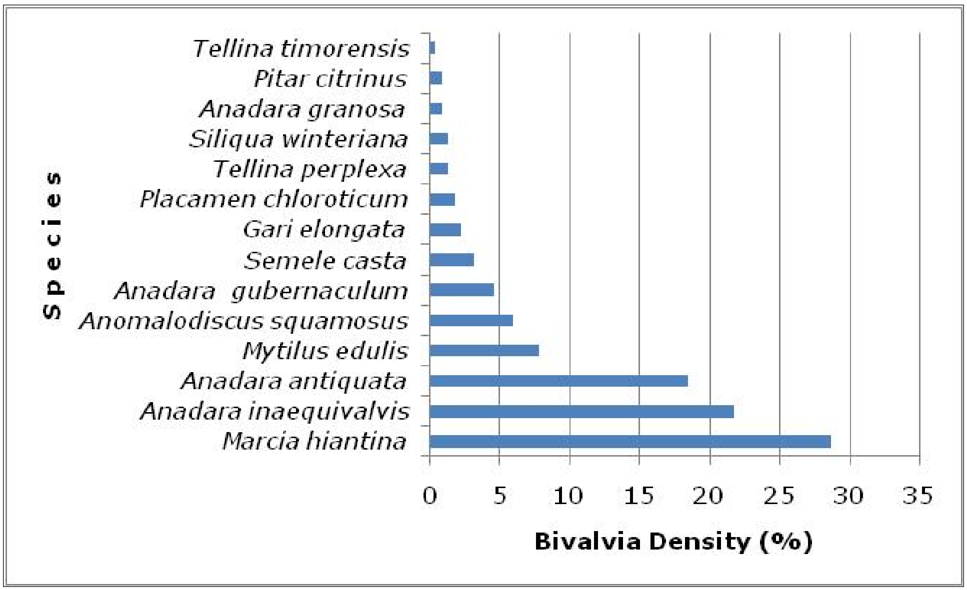

Figure 3. Percentage of bivalve density in rainy season.

Based on Table 3 and Figures 2 and 3, number of bivalve species found is 17 species with 323 individuals in dry season and 14 species with 216 individuals in rainy season. Nkwoji et al (2010) found a total of 872 individuals of macroinvertebrates (12 species) during the dry season and 788 individuals (10 species) during the rainy season, while Akhrianti et al (2014) recorded 16 species of bivalves in the seagrass bed dominated by *Gafrarium pectinatum* (family Veneridae) and *Scapharca pilula* (family Arcidae). Different mollusc composition in Pannikiang island waters was found, 34 species consisting of 20 gastropod species and 14 bivalve species (Hamsiah 2006). Number of species recorded was lower than that recorded during the study. This difference could result from several factors regulating the abundance and the distribution of benthic communities, i.e. water quality, substrate, site, season, and food availability. Bivalves prefer fine sediment habitat, but gastropods do various types of substrates. Arbi (2011) found that mollusc species inhabiting the waters had positive correlation with substrate, for instance, bivalves prefer relatively fine substrate habitat in relation with their feeding behavior (filter feeder). Food filtering more often occurs in finer substrates than in coarse substrate texture.

Number of bivalve families found during the study (dry and rainy seasons) was 9 families of 21 species, Arcidae, Pharidae, Mactridae, Mytilidae, Pinnidae, Psammobiidae, Semelidae, Tellinidae, and Veneridae, dominated by Arcidae (*Anadara* sp.) and Veneridae (*Marcia hiantina*). The bivalve group dominating the mangrove forest and the seagrass bed was Veneridae and this group is the largest group recorded, especially in marine environment estimated about 800 species (Mikkelsen et al 2006; Riniatsih & Widianingsih 2007; Khade & Mane 2012) (Figures 2 and 3). The largest-sized bivalve was *A. vexillum, P. bicolor* and *P. muricata* (family Pinnidae). These species possesses sufficiently wide shell so that epiphytes are sometimes found adhering on the shell. Macreadie et al (2014) uttered that *Pinna* sp. in the seagrass ecosystem is a good site for epitphyte attachment.

Biotic characteristics*.* Ecological index covered diversity indeex (H'), eveness index (J) and richness index (d) (Table 4).

Table 4

Ecological index (diversity, evenness and richness)

Season	*Ecological index*			*∑Species*	*∑Individuals*
	Diversity	*Evenness*	*Richness*		
Dry	2.235	0.969	4.008	17	323
Rainy	1.832	0.950	3.211	14	216

According to Akaahan et al (2014), the diversity index of 1.81–2.91 was categorized as moderate condition, > 3 as stable and equilibrial condition, and < 1 as polluted habitat and damage in habitat structure. Diversity index (H') was found 2.235 in dry season and 1.832 in rainy season. In general, the diversity index of bivalve in Labakkang coastal waters was categorized as moderate meaning that the bivalve condition stability is moderate and has started getting ecological stress. It could result from various activities around Labakkang coastal area that could affect the seagrass ecosystem as bivalve habitat both from land and the water itself, such as residential development, Tonasa cement harbor and transportation to surounding islands, fish ponds, and agricultural disposals through rivers. Water turbidity also influences the presence of seagrasses as bivalve habitat especially in photosynthetic process. Nevertheless, in general other environmental parameters could still be tolerated by the molluscs for their survival. Arbi (2011) stated that high or low diversity index could result from many factors, such as number of species or individuals, substrate homogenity condition, the condition of 3 important coastal ecosystems (seagrass bed, coral reef, and mangrove forest) as aquatic fauna habitas. On the other hand, according to Akhrianti et al (2014), diversity index was affected by number of genera, in which uniform population has higher diversity index than that of non-uniform population.

Genera eveness index (J) was 0.969 (dry season) and 0.950 (rainy season). In general, this value reflects a relatively even species condition and none is dominant. Kharisma et al (2012) claimed that eveness index describes ecological equilibrium of a community, in which the higher the eveness index the better environmental quality is and more suitable for animal life even though there are some species having higher number than the other.

Richness index (d) was about 4.008 (dry season) and 3.211 (dry season). In general, this index is categorized as moderate, based on the species richness index ranging from 2.5 to 4.0 (moderate) (Jorgensen et al 2005). It means that Labakkang coastal waters is not stable due to the presence of various activities affecting it. According to Arbi (2011), the mollusc species richness is influenced by many interrelating factors, especially environmental quality. High or low species richness index is affected by number of species and individuals.

Similarity matrix analysis based on Bray-Curtis index calculation found nMDS ordinance model with 2D stress 0.15 (Figure 4). The model exhibits that the ordinance plot distribution of the bivalves in the dry season and rainy season as grouping and clear separation. It indicates difference in species structure and composition between them in the dry and rainy seasons. Clarke & Gorley (2006) stated that the close points reflected sample similarity in species composition, and distant points indicated differences.

Analysis of Similarity (ANOSIM) indicated significant difference ($p < 0.1$) between dry and rainy seasons with global R of 0.464. The difference level percentage between seasons was 0.1% or 0.001 (significantly different). This Similarity of Percentage (SIMPER) of the molluscs is given in Table 5.

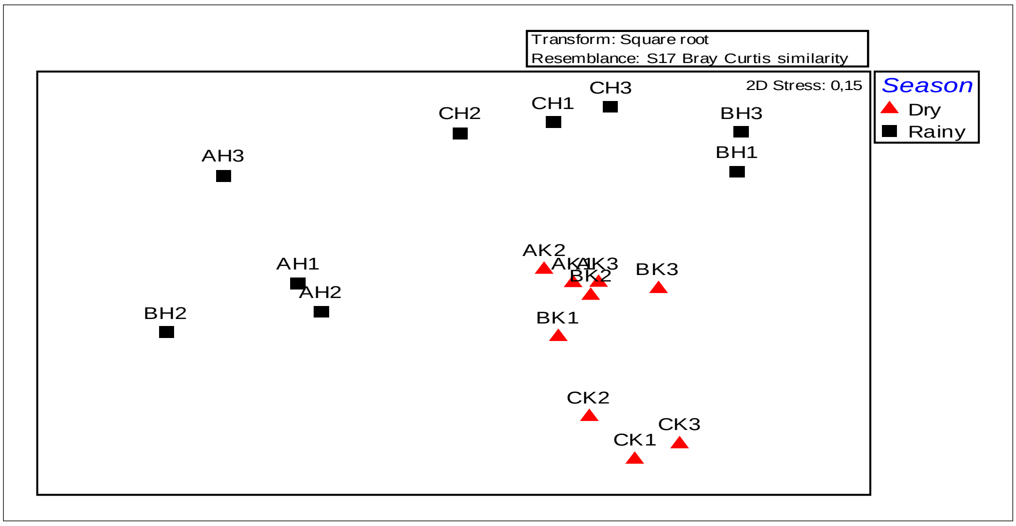

Figure 4. Mollusc nMDS plot in dry season and rainy season.

Table 5

Mean similarity (%) and species contributing to inter-seasonal similarity of the mollusc density

Season	*Mean similarity (%)*	*Species contribution (%)*
Dry	72.40	*Marcia hiantina* (23.90), *Anadara antiquata* (15.42), *Anadara inaequivalvis* (12.93), *A. guberculum* (11.70) and *Anomalodiscus squamosus* (11.49)
Rainy	55.03	*Marcia hiantina* (32.33), *Anadara inaequivalvis* (25.26) and *A. antiquata* (13.32)

Table 5 shows that percent similarity is 72.40% in dry season and 55.03% in rainy season, and the highest species contribution is revealed by *Marcia hiantina, Anadara antiquate* and *Anadara inaequivalvis*. It could result from much higher mean density of these species than the other (Figures 2 and 3).

For bivalve community structure between dry season and rainy season, it was found that mean dissimilarity was 46.55% and the species contributing to this difference were *A. guberculum* (9.19%), *A. antiquata* (9.13%) and *Gafrarium pectinatum* (8.67%). It could result from significant difference in number of species in rainy season and dry season. Species unfound in the dry season were 4 species, *Gari elongata, Mytilus edulis, Pitar citrinus* and *Semele casta,* while those unfound in the rainy season were 7 species, *Atrina vexillum, Dosinia subrosa, Gafrarium pectinatum, Leporimetis ephippium, Mactra grandis, Pinna bicolor* and *Pinna muricata*.

Conclusions. This study found 17 species of bivalves with 323 individuals (dry season) and in the rainy season about 14 species of bivalves with 216 individuals. Dominant bivalves were *Anadara* sp. (family Arcidae), *Marcia hiantina* and *Anomalodiscus squamosus* (family Veneridae). All environmental parameters could still be tolerated by bivalves and seagrasses and still in the range of suitable water quality criteria for marine life.

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