Tropical Seagrass

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Research Article

Differences in Richness and Abundance of Species Assemblages in Tropical Seagrass Beds of Different Structural Complexity

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Abstract

Seagrasses are a major functioning element which maintain the high productivities of tropical marine regions. The structural role of seagrass depends largerly on the amount of material it develops above and below ground. The objective of the study is to analyse how species composition and density of seagrass beds influence associated communities of marine organisms. Seagrass beds were selected based on species composition and density. Seagrass associated flora and fauna including epiphyte, zoo and phytoplankton, fish and macrozoobenthic communities were compared between seagrass beds differed in its structural complexity. This study suggest that there was a variability in diversity and abundance of community assemblages in different structural complexity of seagrass. Variability of the assemblages was associated with the presence or absence of seagrass, density and/or species composition and not specific physical-chemical features.

Key words: Seagrass assemblages, structural complexity, fishes, plankton, epiphytes

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Seagrass beds are widely distributed in the tropical Indo-Pacific region with the highest number of species (24 species) occurring in this region out of 58 species described worldwide (Short *et al*., 2007). They occur in the form of monospecific (constructed by only one species of seagrass) or multispecific beds (constructed by more than one species of seagrass) (Green and Short, 2003).

The presence of seagrasses enhances the marine environment by increasing the amount of physical structure and thereby increasing the available habitat and consequently, increasing the abundance and diversity of marine organisms (Lee *et al*., 2001; Bostrom *et al*., 2006). Leaves and stems of seagrasses support numerous and abundant epiphytes which are fed upon by small epifaunal organisms, such as amphipods and gastropods (Jernakoff and Nielsen, 1998), which, in turn provide food to the fishes and variety of marine organisms foraging in the seagrass beds (Beck *et al*., 2001; Heck *et al*., 2003; Gillanders, 2006; Blandon and Ermgassen, 2014).

Tropical seagrass, especially, is an important food source for mega herbivores such as dugong, green sea turtles and manatees and has an important interaction with mangroves and coral reefs (Adams *et al*., 2006; Short *et al*., 2007; Unsworth *et al*., 2008). In reef systems, seagrass often form an important element providing feeding and nursery areas for coral fishes (De la Moriniere *et al*., 2002; Nagelkerken *et al*., 2001; Dorenbosch *et al*., 2004; Unsworth *et al*., 2008; Kimirei *et al*., 2011).

Despite the critical role of seagrass in the marine environment and to the humanity, seagrass areas are decreasing worldwide with the rate of loss of 27 $km^2 y^{-1}$, it may include the seagrass in the Indo-Pacific region (Orth *et al*., 2006; Waycott *et al*., 2009), the threats on biological diversity of seagrass is also occurred with some species have been reported to be extinct (Short *et al*., 2011), signify the gradual losses of ecosystem services that seagrasses provided.

Seagrass beds within Indo-Pacific region can be highly variable in their shoot density and biomass often over small spatial scale (Kuriandewa *et al*., 2003). The seagrass meadows are commonly occurred in a variety of coverage and density that is comprised of one or more species of seagrasses leads to a view of different degree of patchiness in the seagrass beds with several bare sand patches, as the one found in Spermonde area, South Sulawesi, Indonesia (Amran, 2010). These all factors (seagrass coverage, density, species composition and bare areas in between) create different habitat complexity that might offer a different condition for marine organisms as well (Fonseca *et al*., 2007). The physical nature of the seagrass canopy play a major role, potentially influencing available shelter, food and protection from predators (Stoner and Lewis, 1985; Ambo-Rappe *et al*., 2013; Nadiarti *et al*., 2015; McCloskey and Unsworth, 2015). However, monitoring efforts on seagrass in the tropical Indo-Pacific region is still very limited resulting in lack of data from this region to determine their seagrass status (Waycott *et al*., 2009). Moreover, little is known about the function of different seagrass beds in terms of species and density in supporting marine biodiversity in this region. This information is urgently needed in protection of the remaining seagrass meadows with its biological diversity.

MATERIALS AND METHODS

Study site: The study was performed in June, 2011 at Barrang Lompo Island (5°03'S, 119°20'E), located ca. Fourteen kilometer from the coast and is one of the more than 100 small coral islands in Spermonde Archipelago, westward of Makassar city, South Sulawesi, Indonesia. Barrang Lompo has an extensive shallow reef flat of approximately 100 Ha covered by carbonate sands that hosts a 50 ha multispesific seagrass meadow (Amran, 2010). This meadow is situated at about 20-30 cm above Extreme Low Water (ELW). Semi-diurnal tide in this area shows maximum tidal amplitude of approximately 140 cm, with parts of the seagrass beds are periodically exposed during spring low tide (Sterrenburg *et al*., 1995).

Choice of seagrass station: Seagrass meadow in Barranglompo island has a coverage area of less than 50% which is composed of six species of seagrass (*Enhalus acoroides, Thalassia hemprichii, Cymodocea rotundata, Halodule uninervis, Syringodium isoetifolium* and *Halophila ovalis*). The meadow consists of mixed and monotypic stands with varying in shoot density (Amran, 2010). For purpose of this study, seagrass beds were selected based on their seagrass species composition and density. There were dense multispesific beds, sparse multispesific beds, dense monospesific beds, sparse monospesific beds and bare areas (unvegetated) with three replications on each, totaling 12 seagrass plots and 3 non-vegetated plots. The size of each plot was 10×10 m marked with a bright color of polyethylene rope deployed in the substrate with L-shaped iron pegs. The plot hereafter be referred to DMU-1,2,3 (dense multispesific plot), DMO-1,2,3 (dense monospesific plot), SMU-1,2,3 (sparse multispesific plot), SMO-1, 2, 3 (sparse monospesific plot) and NV-1, 2, 3 (non-vegetated).

Environmental variables: A number of environmental parameters were measured in each plot. Water quality checker was used to measure temperature, salinity, pH, turbidity and dissolved oxygen. Depth was measured by using depth gauge, whereas current speed was determined using flow meter. Water samples from each plot were analyzed for nitrate content using Brucine method and phosphate with ascorbic acide method (APHA., 1989). Organic matter content of the sediment was estimated by measuring the weight loss caused by ignition (difference by dry weight at 105°C and burned weight at 550ºC has been taken as an index of organic matter content). Environmental characteristics of the individual plots are summarized in Table 1.

Seagrass composition and density measurement: Seagrass composition and shoot density measurement were conducted on each seagrass plots (12 plots). In each plot, three 1×1 m quadrates were placed randomly to identify the seagrass species and count for shoot density. If the seagrass plot consisted of more than one species of seagrass, the shoots measurement was done on each species to estimate the total shoot density of the plot. Seagrass composition and density of each plot are described in Table 2.

Sampling of associated flora and fauna: Epiphytic macroalgae was sampled on seagrass leaves as this epiphytic plants is the most abundance and diverse in seagrass and especially seagrass leaves carry more the epiphytes than stem or rhizome (Borowitzka *et al*., 2006). Sampling on the epiphytic macroalgae was conducted in three 0.5×0.5 m quadrates placed in each seagrass plot. A plastic sampling bag was placed over the leaves and all shoots are trimmed of leaves by scissors. The plastic bag was sealed filled with seawater and placed into an iced-insulating box until they are taken to the laboratory. In the laboratory, epiphytes were scraped from all leaf surfaces. The assemblage of epiphytic microalgae further examined under a compound microscope for identification of species using, Carpenter and Niem (1998) and Jha *et al.* (2009). Biomass was measured by drying and weighing seagrass leaves and epiphytes sample found in each quadrate separately and the biomass of epiphytes was then normalized to seagrass leaf biomass.

Fish community associated with seagrass bed was observed and counted in each plot (sparse and dense both in mono and multispesific beds and also in unvegetated area). Survey of fishes was conducted using Underwater Visual Census (UVC) technique follow, English *et al.* (1994) and Sutherland (2006). The observer swam slowly in each plot along a 10 m belt transect, recording fish encountered within 2.5 m on either side, giving a total observed area of 50 m^2. Photograph of fish was also taken using underwater camera in order to double check the fish identification done in the field. Fish was identified to species level (Allen, 1999; Kuiter and Tonozuka, 2001; Carpenter and Niem, 2001). All plots were observed during daylight at periods of high tide where the seagrass beds were fully flooded. The UVC method is efficient for this study due to high water clarity (100% in all plots) as requirement for using this method, even though as any visual observation method in marine vegetated environment, it is likely that small and cryptic species were underestimated (Edgar *et al.*, 2004).

Phyto and zooplankton were sampled in each plot (i.e., on the water surface for phytoplankton and near the bottom for zooplankton). Sampling of both phyto and zooplankton was conducted in the same day during high tide by hand-towed the plankton net (15 cm in diameter, d = 15) from the boat along the plot up to 10 m. For each net the estimated filtered water volume was calculated from the mouth area of net ($3.14xr^2$, r = 1/2d) multiplied by

Table 1: Environmental characteristics in the study sites

Station	T (°C)	S (ppt)	DO (ppm)	pH	Turb (ntu)	D (m)	CS (m sec^{-1})	N (ppm)	P (ppm)	TOM (%)
DMU-1	30.1	31	4.63	7.93	8	0.8	0.044	0.006	0.280	8.52
DMU-2	30.0	30	2.27	7.70	7	0.9	0.012	0.011	0.700	5.88
DMU-3	31.5	30	6.41	0.01	6	0.8	0.56	0.006	0.370	6.92
DMO-1	28.8	29	3.47	7.80	6	1.4	0.019	0.004	0.390	6.42
DMO-2	32.1	30	8.47	8.10	5	0.3	0.15	0.010	0.230	5.40
DMO-3	31.0	29	7.12	8.05	7	0.9	0.068	0.031	0.530	6.34
SMU-1	30.0	30	4.77	7.91	5	0.8	0.036	0.011	0.430	5.78
SMU-2	31.2	30	7.33	8.06	7	0.8	0.011	0.011	0.850	6.82
SMU-3	31.6	31	6.65	8.01	5	0.9	0.024	0.006	0.170	4.74
SMO-1	30.7	30	4.72	7.97	7	0.8	0.008	0.005	0.460	5.42
SMO-2	30.0	30	4.74	7.92	7	1.1	0.047	0.013	0.240	7.36
SMO-3	29.9	30	4.52	7.90	7	1.1	0.028	0.006	0.140	6.34
NV-1	29.4	30	5.85	7.90	9	2.5	0.023	0.009	0.300	4.78
NV-2	30.0	30	9.35	8.14	8	1.2	0.026	0.011	0.120	6.70
NV-3	32.0	29	5.35	7.90	4	2.8	0.119	0.12	0.370	7.62

T: Temperature, S: Salinity, DO: Dissolved oxygen, Turb: Turbidity, D: Depth, CS: Current speed, N: Nitrate content in water, P: Phosphate content in water, TOM: Total organic content in sediment

Table 2: Seagrass composition and density in study sites

Station	Species	Density (shoot m^{-2})	Total density (shoot m^{-2})
DMU-1	*Enhalus acoroides*	52	384
	Syringodium isoetifolium	219	
	Thalassia hemprichii	97	
	Cymodocea rotundata	16	
DMU-2	*Enhalus acoroides*	44	198
	Halophila ovalis	2	
	Thalassia hemprichii	152	
DMU-3	*Enhalus acoroides*	15	258
	Halodule uninervis	133	
	Thalassia hemprichii	37	
	Cymodocea rotundata	17	
	Halophila ovalis	56	
DMO-1	*Enhalus acoroides*	93	93
DMO-2	*Cymodocea rotundata*	609	609
DMO-3	*Enhalus acoroides*	73	73
SMU-1	*Enhalus acoroides*	7	72
	Halodule uninervis	17	
	Thalassia hemprichii	8	
	Cymodocea rotundata	21	
	Halophila ovalis	19	
SMU-2	*Enhalus acoroides*	12	70
	Thalassia hemprichii	9	
	Cymodocea rotundata	37	
	Halophila ovalis	12	
SMU-3	*Enhalus acoroides*	9	67
	Thalassia hemprichii	23	
	Cymodocea rotundata	15	
	Halodule uninervis	20	
SMO-1	*Enhalus acoroides*	11	11
SMO-2	*Enhalus acoroides*	28	28
SMO-3	*Enhalus acoroides*	40	40

DMU-1, 2, 3: Dense multispesific plot), DMO, 2, 3: Dense monospesific plot), SMU-1, 2, 3: Sparse multispesific plot, SMO-1, 2, 3: Sparse monospesific plot)

the distance of the net was towed (10 m). Samples were immediately preserved in 4% formaldehyde solution for species identification and counting (plankter per cubic meter). In the laboratory, phyto and zooplankton samples were identified to the smallest taxonomic groups as possible using some guides (Newell and Newell, 1977; Swadling *et al*., 2008; Suthers and Rissik, 2009). The enumeration was performed at the same time with the help of a Sedgewick-Rafter counting chamber using a compound microscope following standard protocols (Hotzel and Croome, 1999; Dhargalkar and Verlecar, 2004; LeGresley and McDermott, 2010).

Macrozoobenthic organisms were sampled with a 1×1 m quadrate placed in three points in each of 15 plots (both seagrass and non-vegetated). These animals were taken from a sub quadrate (20×20 cm) with five replicates in each 1 m^2 quadrate using a spade up to 5 cm below substrate. The samples were roughly cleaned and rinsed through a 0.5 mm sieve and fixed in 4% formaldehyde solution. The macrozoobenthos was identified at level of species or genera under a dissecting microscope (Dharma, 1988; Dharma and Hemmen, 1992; Carpenter and Niem, 1998).

Data analyses: All biotic parameters measured including epiphytes, phyto and zooplankton, fish and macrozoobenthos assemblages were correlated to different characteristic of seagrass and nonvegetated area using Principal Component Analysis (PCA) in order to obtain information on how the patterns of seagrass beds in terms of species, density and biomass influence the variation of their associated biota. Data on richness and abundance of each assemblage were compared between seagrass with different structure and unvegetated area using analyses of variance (ANOVA) with exception of epiphytes which was only compared between seagrass patches since no seagrass and hence its epiphytes occurred naturally in the unvegetated site. Before doing the ANOVA, all data were tested for normality and homogeneity of variances, where necessary, the data were log (x+1) transformed to meet the requirement. Data that did not meet the requirement even after transformation was analyzed separately using non-parametric test that equivalent of an ANOVA (i.e., Kruskall-Wallis test). *Post-hoc* Bonferroni's tests were conducted to determine individual inter-plot differences when an F-test indicated significant (p-value<0.05).

RESULTS

The environmental conditions were variable within the plots (Table 1), showing no clear direction and no significant correlation (Spearman correlation) to species richness and abundance of seagrass flora and fauna obtained from this study. This independence of biotic and abiotic variables were followed also from results of Principal Component Analysis (PCA) because they have highest loadings on different PCs. Depth was, however, correlated with PC1 (p<0.05), showing that overall abundance and richness of organisms generally decrease with increasing depth.

A total of 26 taxa of epiphytic macroalgae (3 Chlorophyta and 23 Rhodophyta) were found associated with the seagrass leaves in this study. Rhodophyta was dominant with seven families (Corallinaceae, Gracillariaceae, Hypneaceae, Caulacanthaceae, Champiaceae, Ceramiaceae, Rhodomelaceae) composed the epiphyte community structured, compared to Chlorophyta that only contribute to one family (Bodleaceae). Almost half of the epiphyte taxa were originated from Ceramiaceae and Rhodomelaceae. Epiphyte richness and biomass were significantly difference between seagrass sites (ANOVA: epiphyte richness; $F_{3,11} = 33.802$, $p<0.01$, epiphyte biomass; $F_{3,11} = 6.694$, $p<0.05$). *Post hoc* Bonferroni test indicated dense multispesific seagrass (DMU) has significantly higher diversity of epiphytes than others, whereas in terms of associated epiphyte biomass, DMU was similar to other dense seagrass; dense monospesific seagrass (DMO); but different from both sparse seagrass beds, SMU and SMO (Fig. 1a).

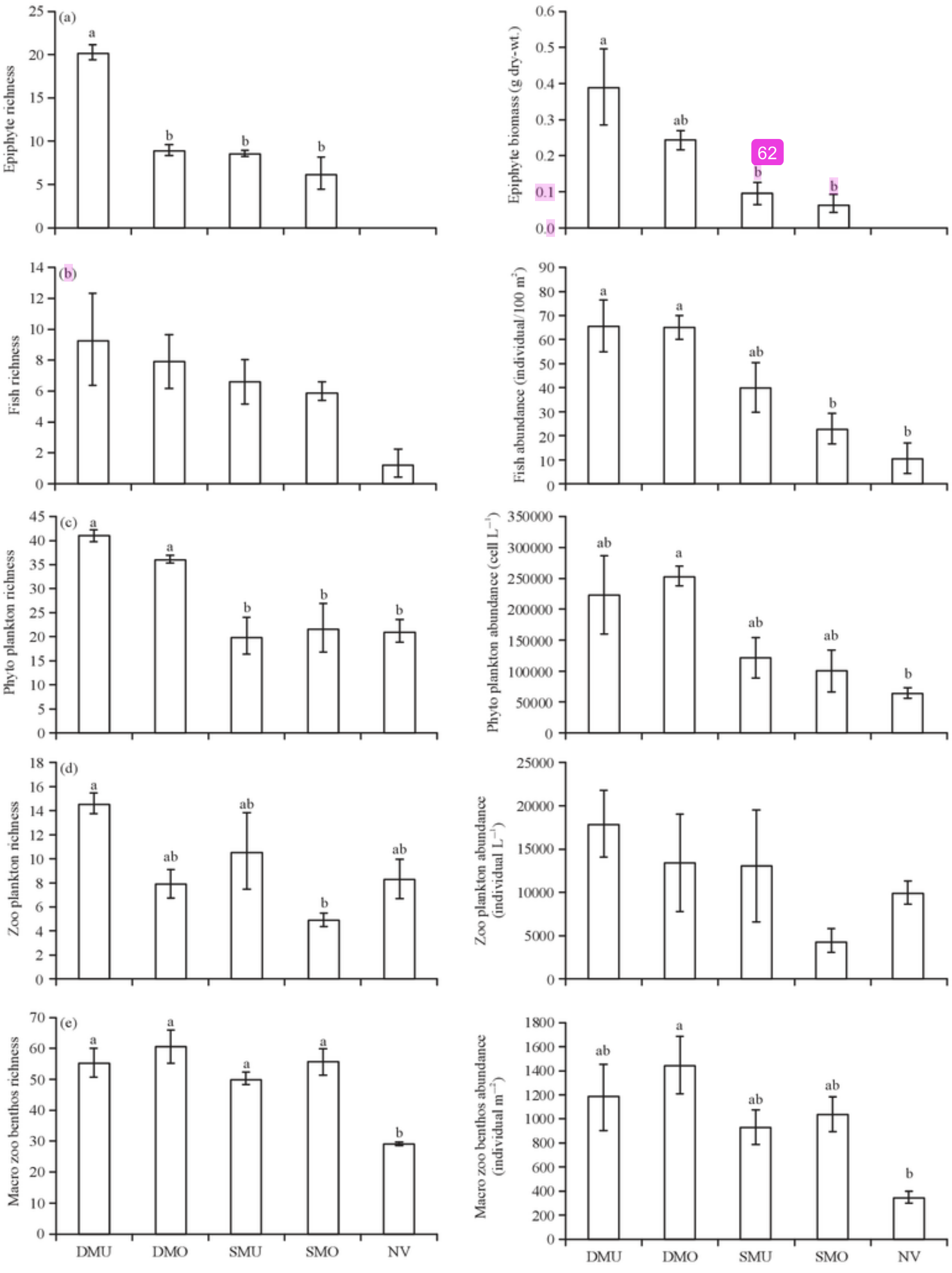

Fig. 1(a-e): Comparison of organisms richness and abundance across the sampling sites: (DMU) Dense multispesific bed, (DMO) Dense monospesific bed, (SMU) Sparse multispesific bed, (SMO) Sparse monospesific bed and (NV) Non-vegetated areas

It was identified 25 species of fish originating from 13 families. Pomacentrids was the dominant family with 7 species, followed by siganids and nemiptherids (3 species each), labrids and gobiids (2 species each) and each one species for gerreids, sphyraenids, muraenids, monachantids, tetraodontids, hemiramphids, serranids and acanthurids. Fish richness showed a higher value in seagrass compared to non-vegetated habitat, eventhough the pattern was not statistically significant (Fig. 1b). However, the abundance of fish was significantly higher in dense seagrass beds, DMU and DMO, compared to sparse monotypic, SMO and unvegetated area ($F_{4,14} = 9.453$, $p<0.01$).

There were 71 taxa of phytoplankton identified in this study. The highest number were Bacillariophyceae (34), followed by Dynophyceae (19), Cyanophyceae (6), Coscinodiscophyceae (6), Fragillariophyceae (5) and Noctiluciphyceae (1). Phytoplankton diversity was significantly higher in both dense seagrass, DMU and DMO compared to sparse seagrass beds and unvegetated habitat. While abundance of the phytoplankton was significantly higher in DMO only in comparison to unvegetated habitat (ANOVA: phytoplankton richness; $F_{4,14} = 9.962$, $p<0.01$, phytoplankton abundance; $F_{4,14} = 5.013$, $p<0.05$) (Fig. 1c).

Altogether there were 30 zooplankton taxa representing 12 groups found in this study. Copepods with 12 taxa were the dominant group shaped the overall zooplankton structure. Zooplankton abundance was not different between different structure of seagrass and also with non-vegetated habitat. However, the diversity of zooplankton was significantly higher in dense multispecific seagrass, DMU compared to sparse monotypic seagrass, SMO ($F_{4,14} = 4.221$, $p<0.05$) (Fig. 1d).

A total of 129 macrozoobenthos taxa representing 6 groups identified in this study. The higher number were gastropods (99), followed by bivalves (25), crustaceans (2) and each 1 taxa for scaphopods, polychaetes and sipunculids. Macrozoobenthic community (Fig. 1e), for species richness, showed a higher value in seagrass than in unvegetated area ($F_{4,14} = 10.217$, $p<0.01$). Whereas, abundance of this community was significantly higher in dense monotypic seagrass, DMO, compared to unvegetated area ($F_{4,14} = 4.655$, $p<0.05$).

Principal component analysis, which included all the variables, both biotic and environmental variables showed that all biotic variables have high loading only to the PC1 (explaining 38.3% of total variance), ranging from 0.56-0.92, whereas, environmental variables do not (excluding depth with loading was 0.63). Thus PC1 probably reflects overall richness and abundance, which are significantly and positively correllated ($p<0.01$) with each other for all the groups of organisms studied. Some environmental variables such as temperature, pH, turbidity, dissolved oxygen, sediment composition and current velocity showed rather high (from 0.48-0.76) loading on the PC2 (explains 13.5% of total variance), thus PC2 can be interpreted as related to abiotic variables which however interrelated notably weaker than biotic ones. Only these two PCs showed significant ($p<0.05$) differences between the stations, thus other PCs were not analyzed (they explained 11% or less of total variance each).

The PC analysis of biotic variables (excluding seagrass which was considered as categorical variable) also resulted in two PCs significantly differing between the stations, PC1 and PC2 explained 61.5 and 13.7% of total variance respectively. In a whole, all biotic variables greatly contribute to PC1 (loading from 0.57-0.92), which thus refers overall richness and abundance. However, loading of zooplankton and macrozoobenthos is somewhat lower than others and the two latter have highest contributions to PC2 but with different signs (Table 3). Therefore this PC describes some spesific patterns of distribution of zooplankton and macrozoobenthos which are not related to overall abundance of associated biota.

Because area of the study is quite small and even the most distant stations are situated within a distance about 2 km, we checked whether similarity between the stations is caused by their geographical proximity. For that we correllated geographical distances between all the stations with distances in structure of biota which were determined in coordinates of PC1 and PC2 are given in equation:

$$(d_{a\text{-}b} = \sqrt{}(PC1_a\text{-}PC1_b)^2+(Pc2_a\text{-}PC2_b)^2)$$

where, d is the distance between stations a and b in PC1 and PC2 coordinates. Correlation coefficient between these two types of distances was rather low, r = 0.043 (NS), showing that

Table 3: Result of principal component analysis of biotic variables. Loadings of variables on PCs and proportion of total variance explained by PCs

Variables	PC1	PC2
EP-R	-0.822	-0.140
EP-B	-0.925	-0.081
FI-R	-0.771	0.255
FI-A	-0.937	0.008
PH-R	-0.748	0.002
PH-A	-0.727	0.017
ZP-R	-0.573	-0.764
ZP-A	-0.664	-0.498
ZB-R	-0.765	0.548
ZB-A	-0.837	0.383
Proportion of total variance (%)	61.5	13.7

EP-R: Epiphytes richness, EP-B: Epiphytes biomass, FI-R: Fish richness, FI-A: Fish abundance, PH-R: Phytoplankton richness, PH-A: Phytoplankton abundance, ZP-R: Zooplankton richness, ZP-A: Zooplankton abundance, ZB-R: Macrozoobenthos richness, ZB-A: Macrozoobenthos abundance

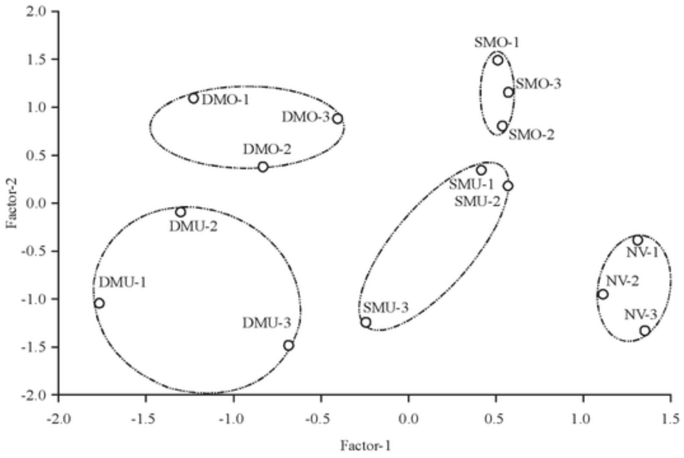

Fig. 2: Position of sampling sites in dimensions of PC1 and PC2 showing a clear separation between (DMU) Dense multispesific bed, (DMO) Dense monospesific bed, (SMU) Sparse multispesific bed, (SMO) Sparse monospesific bed and (NV) Non-vegetated areas

similarity between stations in structure of biota is not caused by their geographical proximity, i.e., by direct exchange of organisms.

Stations occupy clearly different position in dimensions of PC1 and PC2 (Fig. 2). Abundance/richness of associated biota consequently increase (or PC1 decreases, given negative loadings of abundance/richness on this PC) in a following raw: bare area (no seagrass)-sparse monospecific (26 plants m^{-2}), sparse multispecific (70 plants m^{-2}), dense monospecific (258 plants m^{-2}), dense multispecific (280 plants m^{-2}). Biomass of seagrass is quite similar between monospecific and multiscpecific beds and overall abundance/richness is different only between mono-and multispecific beds. The PC2 shows evident differences between multi or monospecific beds regardless density of seagrass. In particularly, some components of zooplankton are more abundant in multispecific seagrass beds but there are components of macrozoobenthos which are associated specifically with monospecific seagrass beds. For instance, overall abundance and richness of macrozoobenthos is higher in monospecific beds than in multispecific. These differences are not significant but became significant ($p<0.01$ for abundance; $p<0.05$ for richness) if to combine multispecific beds and unvegetated areas.

DISCUSSION

Selection by organisms to seagrass habitat may be influenced by several factors including habitat structures which leads to different in habitat suitability, food availability and protection provided. We found that Rhodophyta was dominant in macroalgal epiphyte community structure on seagrass leaves in this study, especially Ceramiceae and Rhodomelaceae. These two families have been reported mainly live as an epiphyte in the marine environment (Cribb, 1983). More diverse of epiphytes was especially found in dense meadow of multispecific seagrass. This may be related to diverse of substratum provided by different species of seagrass which leads to many different epiphytes able to find their suitable substrate for attachment.

Epiphytes are the prominent component of most seagrass ecosystems. They are also the primary food resource for grazers. The epiphyte abundance and species composition are heavily influenced by the seagrass species which is related to the variation of leaf turnover of different species of seagrass (Chung and Lee, 2008). Faster leaf turnovers limit the time for colonization of epiphytes compared to the slower ones. The size of seagrasses and the rate of seagrass turnover are important in determining the loads of epiphytic organisms attached to them (Borowitzka *et al*., 2006). Therefore, the difference of seagrass bed in terms of number of species (mono or multispesific) will influence the diversity and biomass of epiphyte attached to seagrass leaves in such meadows. Higher diversity of epiphytic macroalgae in dense seagrass meadows illustrates their importance in forming the complexity of seagrass community leading to higher biodiversity in these meadows.

Fish community found in this study was dominated by coral reef species (Allen, 1999; Carpenter and Niem, 2001; Kuiter and Tonozuka, 2001). The similar finding was also found by previous study in this area by Erftemeijer and Allen (1993). This is because the seagrass in this area associated with the reef system, therefore become an important habitat for coral reef fishes, as previously described that seagrass beds are important for coral fishes as nursery and feeding ground (De la Moriniere *et al.*, 2002; Nagelkerken *et al.*, 2001; Dorenbosch *et al.*, 2004; Unsworth *et al.*, 2008; Kimirei *et al.*, 2011).

Fishes were also found to be more abundant in dense seagrass meadows compared to unvegetated or sparsely seagrass beds which may reflect the increased in protection ability and food abundance provided by denser seagrass meadows (Bell and Westoby, 1986; Hyndes *et al.*, 2003). This finding was concurred with Lewis and Stoner (1983) who found infaunal and epifaunal macroinvertebrates are significantly more abundant and represented by greater number of species in seagrass beds than in unvegetated or sparsely vegetated area.

Higher diversity of fish occurred in the dense meadows was also supported by higher richness and biomass of epiphytes found in the denser beds which can be a food source for the fish (Borowitzka *et al.*, 2006). The epiphytic algae associated with seagrass are important primary producers in seagrass ecosystems and make a significant contribution to food webs (Fong *et al.*, 2000), they contributed 62, 50 and 44% of primary production for *Syringodium filiforme*, *Thalassia testudinum* and *Halodule wrightii*, respectively (Wear *et al.*, 1999), 19-37% for *T. hemprichii* (Heijs, 1984) and 2-9% for *Enhalus acoroides* (Brouns and Heijs, 1986). The data show that the contribution of epiphytic algae to the primary production of seagrass bed might be affected by the seagrass species which compose one bed. In this study, it was found that the contribution of epiphytic macroalgae in monospesific seagrass beds of *Enhalus acoroides* or *Cymodocea rotundata* was 0.6-1.5%, the contribution was higher in multispesific beds which 1.2-3.0% of the total leaves biomass.

Besides the epiphytes, fish in seagrass prey on phyto and zooplankton. In this study, both phyto and zooplankton were more diverse in dense seagrass multispecies meadow and relatively more abundance in the dense meadows as well. These finding support the occurrence of more fish in dense seagrass beds in this study. Bacillariophyceae (diatoms) were found more abundant in this study, this may be because the seagrass meadows positioned in the shallow area of the shore where favors diatoms development due to a well mixing of the water column (Jarry *et al.*, 1990; Rakhesh *et al.*, 2008; Mabrouk *et al.*, 2011) and for zooplankton, copepods was the most dominant. The higher diversity and abundance of phytoplankton in these beds may be a reason of the concurrently higher diversity of zooplankton, especially copepods, because of higher food availability (phytoplankton) to the zooplankton, which was in agreement with Rakhesh *et al.* (2008).

It was generally accepted that few fish feed directly on living seagrass material but rather the role of seagrass in marine food webs was mainly as detritus consumed by invertebrates (Hyndes and Lavery, 2005). More biomass of seagrass and associated flora and fauna will affect the benthic structure in the substrates in which more organic fall down from the dense beds compared to sparse or unvegetated area. We found more diversity and abundance of macrozoobenthos in dense seagrass bed compared to unvegetated area. This is in line with some studies that have shown that seagrass beds host more diverse and abundant benthic communities than unvegetated areas (Arrivillaga and Baltz, 1999; Bostrom and Bonsdorff, 2000; Attrill *et al.*, 2000). Higher diversity and abundance of macrozoobenthic community in especially denser seagrass in comparing to the unvegetated sediment indicated the dependence of these communities on the available food (detritus) in the sediment where the detritus is mainly contributed from the decaying seagrass and associated macroalgae. Protection ability of seagrass meadows to this fauna is also considered higher than unvegetated area and the ability of these plants to modify currents, promotes sediment deposition and provides suitable habitat for the benthic organisms (Fonseca and Fisher, 1986). The components of benthic communities, particularly those of seagrass beds were previously found abundant and rich in species in denser and more complex seagrass beds (Edgar, 1990; Paula *et al.*, 2001).

Abundance and diversity of biota associated with seagrass described above are positively correlated with each other. Thus one can say about overall abundance/richness represented by PC1, which demonstrated clear patterns. First, abundance and richness are higher in the denser seagrass beds but this relationship with biomass of seagrass is weaker. This may show that density of seagrass is more important for associated biota than biomass. Second, some spesific components of zooplankton and especially, macrozoobenthos are different in multi or monospecific seagrass beds regardless of their density.

CONCLUSION

The results of this study suggest that scale of a small island with relatively homogenous environment could detect the variability in diversity and abundant of faunal assemblages in different structural complexity of seagrass. Variability of community assemblages was associated with the presence or absence of seagrass, density and/or species composition and not specific physical-chemical features. This indicates the important of structural complexity of seagrass in maintaining marine biodiversity. Therefore, conservation and even rehabilitation is urgently needed to prevent the decline of seagrass area and diversity as both variables is necessary to ensure and enhance the seagrass ecological functioning in marine ecosystem.

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