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A Comparison of Fish Distribution Pattern in Two Different Seagrass Species-Dominated Beds in Tropical Waters

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Abstract: Seagrass beds dominated by *Thalassia hemprichii* (TH) and *Enhalus acoroides* (EA) have different complexity structure which in turn will affect fish assemblage structure within the seagrass beds. This study was aimed to compare fish distribution and assemblage structure in both seagrass beds including: fish life stage and fish size distribution. Fish assemblage structure was analyzed using non-metric multidimensional scaling technique and Bray-Curtis cluster analysis while the most contributed species to difference of fish assemblage structure was analyzed using SIMPER (similarity of percentages) procedure. All statistics analysis were carried out using PRIMER v6 Software. The difference between fish distribution in both seagrass beds was analyzed with t-test and Bonferroni post-test using PRISM v5 Software. It can be concluded that fish assemblage structure and distribution pattern in TH and EA-dominated seagrass beds were significantly different, although, there was general trend that the seagrass was an important habitat for fish juveniles. It implies the urgency for the management of seagrass beds to maintain their function in supporting fishery especially in juvenile stage. Future similar works are necessary for sustainable fisheries management development, especially in the threatened seagrass habitats.

Key words: Fish assemblage structure, fish life stage, *Thalassia hemprichii*, *Enhalus acoroides*, habitats

INTRODUCTION

Seagrass meadows are important marine resources for fisheries at either local or regional level as they support various marine fish and shellfish. They provide space for living, foraging, shelter and protection, particularly in the nursery stage (Nagelkerken and Van der Velde, 2002; Heck *et al*., 2003; Gillanders, 2006). Several studies have focused on fish structure community in seagrass beds, showed that dense seagrass meadows harbor more abundant fish compared with the adjacent patches of removed seagrass and bare areas (Tuya *et al*., 2005; Smith *et al*., 2008). The structural complexity or heterogeneity of the seagrass habitat (i.e., different species composition, plant morphology and meadows architecture) has been considered as a factor affecting the fish assemblages (Gullstrom *et al*., 2002; Hyndes *et al*., 2003). Khalaf *et al*. (2012) approves that fish assemblage structure affected by the structural complexity of the substrate and the live benthic cover.

The most common and abundant tropical seagras species in Indonesian waters, *Thalassia hemprichii* and *Enhalus acoroides* (Tomascik *et al*., 1997) have similar strap-like leaves shapes but different in length and wide. *T. hemprichii* has shorter leaves (10-40 cm long, 0.5-1 cm wide) compare with the much greater leaf lengths of *E. acoroides* (30-150 cm long approximately, 1-2 cm wide). For this reason, structural architecture of seagrass beds dominated by *T. hemprichii* will be different with the one dominated by *E. acoroides* because they will provide different canopy height during high tide or when they submerged in the waters and hence they may harbor fish in different assemblage structures.

Few studies have been done on comparison between fish assemblage in *Enhalus acoroides* and in

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Thalassia hemprichii dominated beds (Nakamura and Sano, 2004; Gullstrom *et al*., 2008). Nakamura and Sano (2004) found that there is no significant difference between fish assemblage structure in both seagrass beds while Gulltsrom *et al*. (2008) found the opposite results. Such comparison study of fish assemblage structure in Southeast Asia is still limited, except for few studies on fish assemblage in the seagrass beds (Nienhuis *et al*., 1989; Unsworth *et al*., 2007; Vonk *et al*., 2008). Comparison of various fish sizes (including juvenile and small inconspicuous adult fish) between both of these seagrass beds in Southeast Asia is also still remain unknown. The objective of this study is to measure and compare the fish assemblage structure and their distribution between both of the seagrass beds including fish life stages and fish size distribution.

MATERIALS AND METHODS

Study area: This study took place in waters surrounding Kapoposang Island (04°41-04°43'S and 118°56-118°59'E). The island is located within the region of Spermonde Archipelago in the waters South West of South Sulawesi and very close to the edge of continental shelf (Fig. 1). Kapoposang is coral island, comparable to several islands within the archipelago (e.g., Barrang Lompo Island and Langkai Island) surrounded by large intertidal reef flat which consist of coarse carbonate sand and coral rubble (93-100% $CaCO_3$) with extensive multi-species seagrass vegetation.

Fish sampling and data processing: Fish population was sampled at the permanent two different sites of the densest seagrass beds which are dominated by *Thalassia hemprichii* (TH site) and by *Enhalus acoroides* (EA site) (Fig. 1). TH site is located in North-West part of Kapoposang Island, comprising three mixed seagrass species (*T. hemprichii*, *C. rotundata* and *S. isoetifolium*) and coral (average seagrass cover of *T. hemprichii* was 74.2 of 84.2%) while EA site is situated in North part of the island, consisted of five mixed seagrass species, minor algae and coral. Seagrass cover of *E. acoroides* was 75 of 95.8%. These seagrass beds were continuous and dense from the shore to over 100 m off the coast to deeper sub-tidal areas where coral habitats begin to dominate.

There were two types of gear (beach seine and monofilament gill net) were applied within 400 m^2 of each sampling site following Nurdin. The fish samples was taken for 9 days consecutively in each sampling site. All fish specimens were sorted, stored on ice and frozen for further analysis. In the laboratory, the specimens were identified, counted and measured for Total Length (TL) to the nearest cm. The fish samples were identified to the lowest taxonomic level possible following Kuiter and

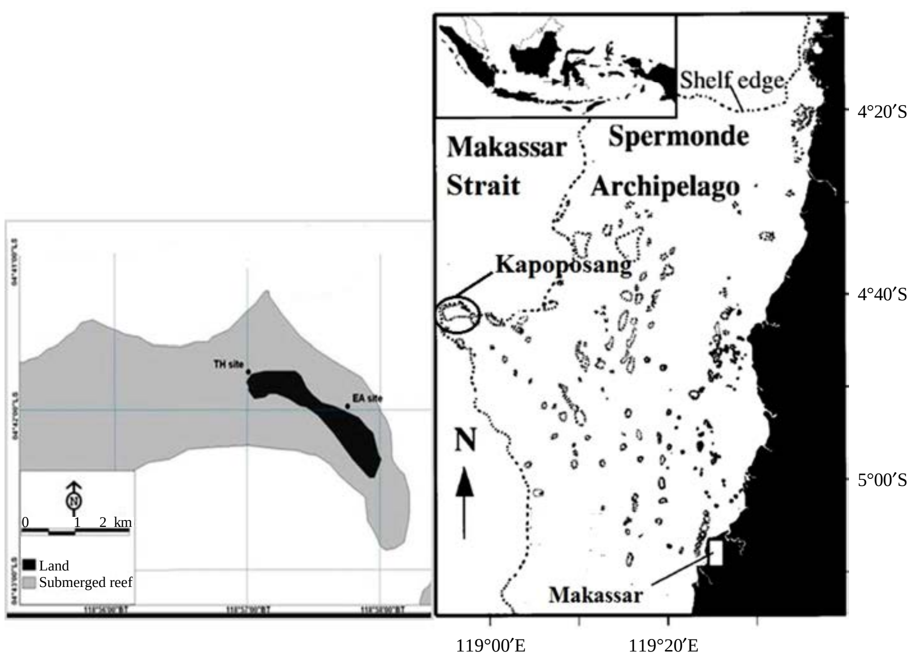

Fig. 1: Map of Spermonde Archipelago South Sulawesi and the study area mentioned in the text. Nadiarti (left), modified from Stapel (right). Seagrass beds dominated by *Thalassia hemprichii* (TH site) and dominated by *Enhalus acoroides* (EA site)

Tonozuka (2001), Kimura and Matsuura (2003) and then individually counted and measured for Total Length (TL) to the nearest cm. Gut of each fish samples (except for fish with <TL 3 cm) were then removed before drying the fishes at 70°C until constant Dry Weight (DW). Fish density (based on fish individual number) and biomass DW (based on constant weight after fish drying) were then calculated at each sampling sites following Nadiarti.

The life stages were separated into 3 groups (juvenile, subadult and adult) according to species' maximum lengths and following Nagelkerken and Van der Velde (2002), Gullstrom *et al.* (2008). Thus, the fish of <1/3 maximum length was categorized as juvenile, 1/3-2/3 of the maximum length (subadults) and >2/3 maximum length (adults). Distribution of life stage group was then calculated in each sampling site. Mean fish density in each sampling site was calculated in four different interval size classes (2.5, 5, 10 and 20 cm) for assessment on utilization of seagrass habitat type in relation to fish size.

Data analysis: Spatial variation of fish assemblage structure based on life stage in each sampling site were analyzed for total density and total biomass in Dry Weight (DW) using non-metric Multidimensional Scaling (nMDS) technique and Bray-Curtis cluster analysis using the computer package PRIMER Software package v6 (Clarke, 1993). Similarity, pattern of the nMDS ordination were based on Bray-Curtis similarity index. In order to minimize the effect of rare and extremely abundant species, the data were first square root transformed creating a rank of similarity matrix. The results were then converted and plotted on a 2D scaling (MDS) plot. Stress values calculated by the MDS procedure is a measure of how well the sample relationship were indicated by the dimension. MDS providing a usable picture of sample relationships (the closer two sites are on the plot, the closer their community composition) when the value is <0.2 (Clarke, 1993). The Similarity of Percentages (SIMPER) procedure was conducted to ascertain which fish species contributed most to dissimilarity of fish assemblage structure between the two of sampling sites. Significant difference of total fish assemblages, size class, juvenile, subadults, adults (for density and DW) between the sampling sites were analyzed using t-test and bonferroni post-test analysis through PRISM Software package v5.

RESULTS AND DISCUSSION

Assemblage structures among fish life stages: A total of 1379 fishes from 63 taxa (of which 62 have been identified to species level) and 31 families were caught at all sampling sites during the study and the top three dominant captured species were *Apogon bandanis* (32%), *Atherinomorus lacunosus* (20%), *Lethrinus harak* (10%) and others (38%). Mean fish density (Fig. 2a) and mean fish DW (Fig. 2b) of juvenile and adult stages did not significantly differ between TH and EA sites. However, sub-adult fish density at TH site was significantly higher (9.00±0.41; Bonferroni post-test result: $p<0.01$) compared with EA site (6.26±1.07). In contrast, sub-adult fish DW at EA site was about >15 times higher (144.17±40.48; Bonferroni post-test: $p<0.001$) in comparison with TH site (6.76±1.90).

The MDS ordination of the fish life stages in density (Fig. 3a) and in DW (Fig. 3b) display clear pattern of each stage group. Supporting results of pairwise comparison tests (one-way layout ANOSIM) among all groups for fish density showing that all groups were significantly different ($R = 0.54$-1.00, $p<0.01$). Comparable to the results of density data, an additional pairwise comparison tests of fish life stage assemblage composition on DW also revealed significant difference among fish groups ($R = 0.52$-1.00, $p<0.01$).

SIMPER analysis indicated that dissimilarities among fish life stages for density over the TH and EA sites were

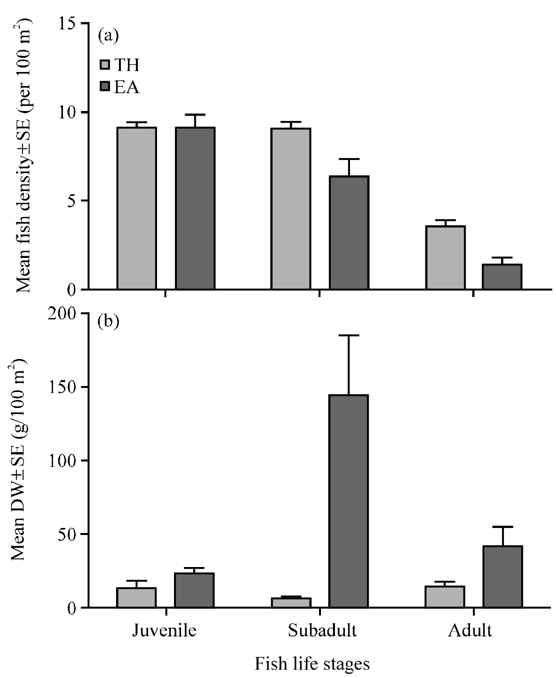

Fig. 2: a) Mean fish density and b) mean fish dry weight of juvenile, subadults and adults stages at TH and EA sites. Error bars indicate standard error of the means

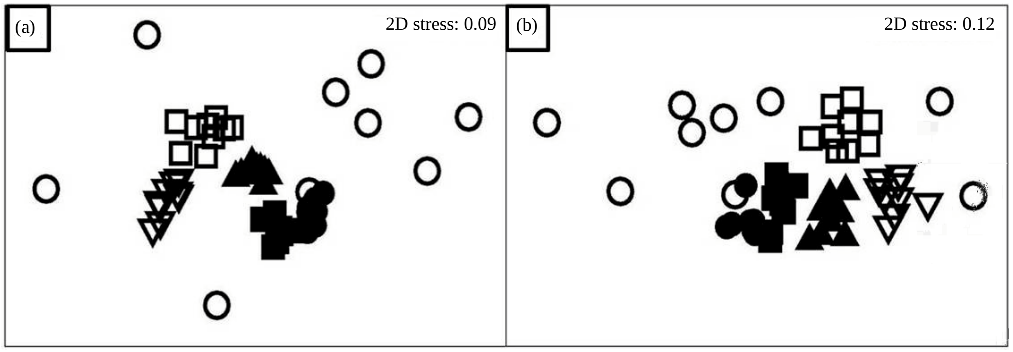

Fig. 3: a) Two dimensional nMDS ordination of fish life stage for density and b) biomass DW; Juveniles at TH site (▲), subadults at TH site (■), adults at TH site (●), juveniles at EA site (▽), subadults at EA site (□), adults at EA site (○)

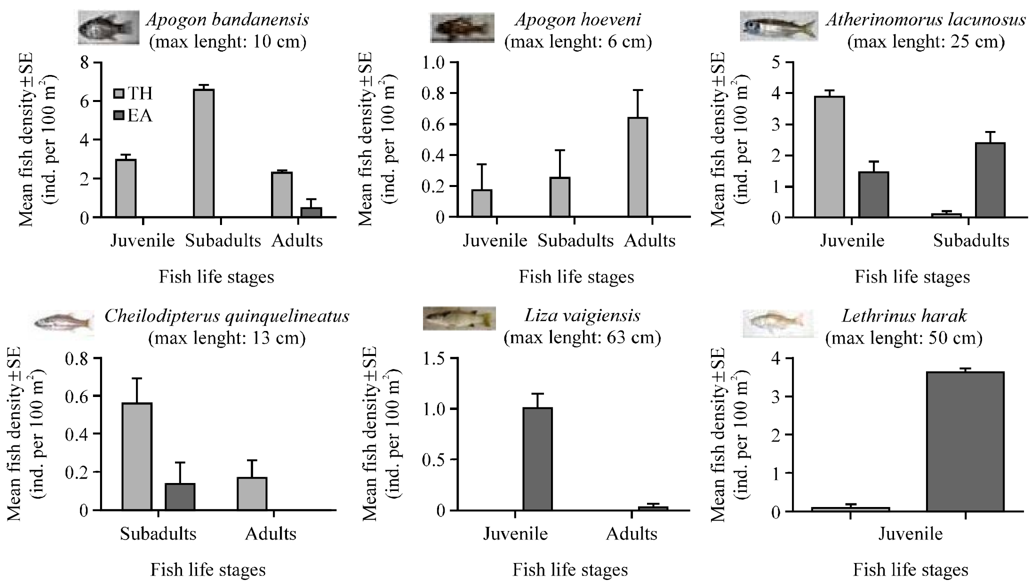

Fig. 4: Mean density of fishes that most contribute (>10%) to differences among life stages at TH and EA sites. Error bars indicate standard error of the means

mostly above 68%, excluding lower dissimilarity between subadults and adults of TH sites (56.14%). In these cases, *Apogon bandanensis*, *Atherinomorus lacunosus*, *Apogon hoeveni*, *Cheilodipterus quinquelineatus*, *Lethrinus harak*, *Liza vaigiensis*, *Tylosurus crocodilus* (some of them were the most abundant species of total fish caught during the study) were responsible to the dissimilarities (percentage contributions >10%, Fig. 4).

Similar results of another SIMPER analysis among fish life stages for DW over both sampling sites also showed lower dissimilarities between subadults and adults of TH sites (66.95%) compare with other dissimilarities that were mostly in the range of 84.57-100%. *Lethrinus harak*, *Apogon bandanensis*, *Siganus canaliculatus*, *Hemiramphus far*, *Strongylura incisa*, *Gerres oyena* were the species that mainly contributed (>10%) to these cases (Fig. 5).

Fish size distribution: The study result of distribution of fish size classes (Fig. 6) was consistent with the result of life stage distribution showing that small fish was more abundant in TH site, especially in the class range of ≤12.5 cm (Table 1). Meanwhile, the fish density at EA site represented more variety of size classes (Fig. 6). Bonferroni post-test results showed significant differences ($p<0.05$ to $p<0.001$) of each size class (except for the size class of 40.0-50.0 and 70.0-90.0) between TH and EA sites.

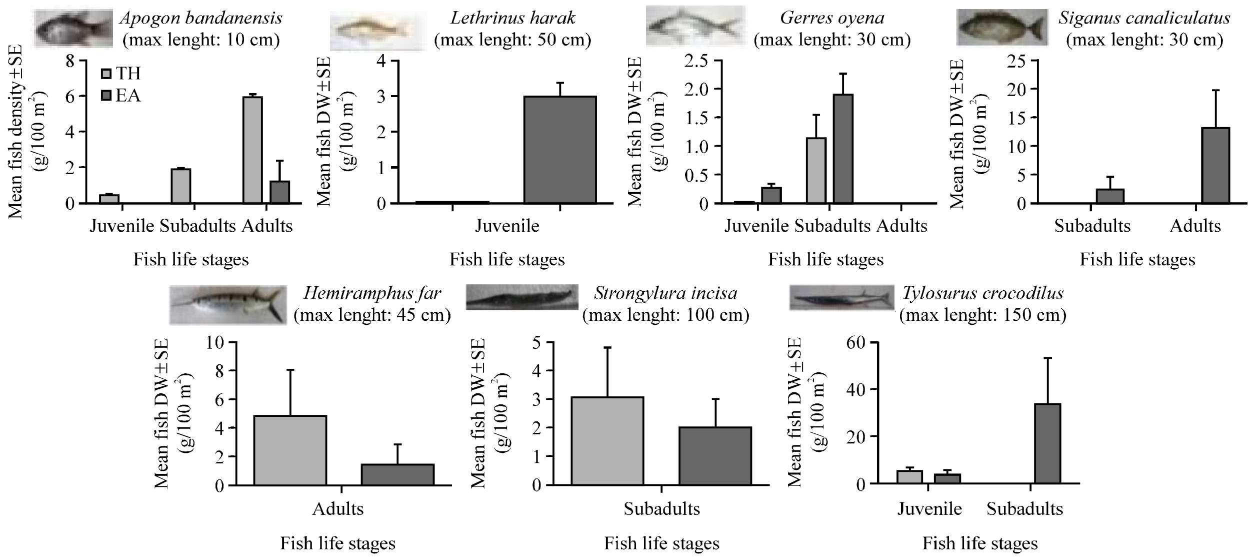

Fig. 5: Mean fish Dry Weight (DW) of fishes that most contribute to differences among life stages at TH and EA sites. Error bars indicate standard error of the means

Table 1: Dominant fish sizes found in the seagrass beds dominated by *Thalassia hemprichii* in Kapoposang island. Total length is presented as cm. Fish life stage is presented as J for juveniles, S for subadults, A for adults. Maximum length is presented as cm

Family	Species	Total length	Life stage	Maximum length[a]
Acanthuridae	*Acanthurus triostegus*	6.5	J	27
	Ctenochaetus sp.	7	S	18
Apogonidae	*Apogon angustatus*	4, 7.5	S, A	11
	Apogon bandanensis	3-5, 6-7	J, S, A	10
	Apogon hoeveni	1.7, 3-4, 5.8-6	S, A	6
	Apogon melas	5, 6	S	13
	Fowleria aurita	5, 6-7	S, A	9
	Cheilodipterus quinquelineatus	5.9-7	S	13
Atherinidae	*Atherinomorus lacunosus*	2.5, 3-5, 6	J	25
Chanidae	*Chanos chanos*	4	J	18
Gerreidae	*Gerres oyena*	3, 6	J	30
Lethrinidae	*Gymnocranius griseus*	3-5	J	35
	Lethrinus harak	4-5	J	50
	Lethrinus lentjan	3, 6.5	J	52
	Lethrinus ornatus	2.4-2.5, 3-5, 7	J	45
Lutjanidae	*Lutjanus boutton*	4	J	35
Holocentridae	*Neoniphon argenteus*	6.5	J	25

[a]Data taken from Froese and Pauly (2011)

The higher occurrence of juvenile fish than adults in the seagrass beds either dominated by *T. hemprichii* or *E. acoroides* support the previous works that seagrass is an important nursery habitat for some fish spesies (Nagelkerken and Van der Velde, 2002; Nuraini *et al*., 2007; Unsworth *et al*., 2007). Of the 11 species (Fig. 4 and 5) that mostly contributed (in density and biomass) to dissimilarities among life stages in all sampling sites, there is an implication that smaller fish (either juvenile or small inconspicuous adult fish) tend to assemblage in TH site and vice versa in EA sites. The exception is found on the larger adult fish, *Hemiramphus far* in which they tend to utilized TH than EA sites. The *H. far* is not competing with those smaller fish that were mostly carnivorous (e.g., Apogonidae, Table 1) because the *H. far* consume seagrass leaves as found in their stomach during the study.

Among the 11 fish species that mostly contributed to dissimilarities, three species of Apogonidae (*A. bandanensis*, *A. hoeveni* and *C. quinquelineatus*) mainly present in the seagrass bed dominated by *T. hemprichii* (Fig. 6). This is may be due to the minor coral coverage within the *T. hemprichii* dominated bed. These three fish species have been recorded on coral substrate (Gardiner and Jones, 2005) indicating the preference of coral fishes on the seagrass beds with more corals association.

Fish size class distribution in this study showed that fish assemblage in the seagrass bed dominated

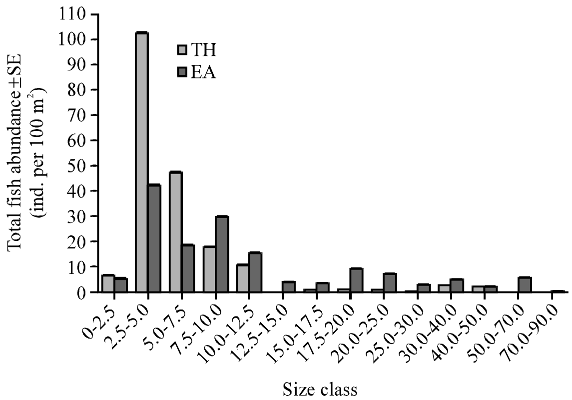

Fig. 6: Mean fish density of several different size classes at seagrass bed dominated by *Thalassia hemprichii* (TH site) and seagrass bed dominated by *Enhalus acoroides* (EA) site. Error bars indicate standard error of the means

by *T. hemprichii* was majority small fish (juvenile and/or small, inconspicuous adult fish, Table 1), however in the seagrass bed dominated by *E. acoroides* harbored larger fishes. This is relevant with previous resaerch done by Nurdin who found more number of smaller fish in TH site and vice versa in EA site. Explanation for this study results could be comparable to the results found by Schultz *et al.* (2009) who found that fish predators preferred seagrass habitat than the adjacent bare areas and vice versa to the juvenile fish that preferred bared sediment to vegetated habitats. Similar to TH site, although the seagrass cover in this site was high (84.2%) and it is not an unvegetated habitat but the seagrass structural complexity in this site was much lower than in EA site because the seagrass bed in TH site was consisted of small seagrass species only and of course they have lower canopy heights compare with the seagrass beds in EA site where it was dominated by the much bigger seagrass species, *E. acoroides* which provide much higher canopy heights (>1 m). As a result, EA site facilitating the improvement of predation efficiency for some larger predators such as *Choerodon anchorago*, *Dyodon histrix* and *Saurida gracilis* and accordingly, smaller fish (including juvenile and small inconspicuous adult fish) preferred TH site as this site provide lower canopy heights that is not beneficial for predators.

CONCLUSION

There are significant differences of fish assemblage structure and distribution pattern in different complexity and structural architecture of seagrass beds in the Indonesian Spermonde Archipelago. However in general, seagrass beds are important habitat for fish juveniles, although, small fish in size prefer seagrass beds with lower canopy height. Overall, the outcomes of this study imply the urgency for the management of seagrass beds to maintain their function in supporting fishery, especially in juvenile stage. Similar studies in other area of Indonesian waters are required to provide a contribution for sustainable fisheries management development, especially in the threatened seagrass habitats.

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