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Seagrass biodiversity at three marine ecoregions of Indonesia: Sunda Shelf, Sulawesi Sea, and Banda Sea

MUJIZAT KAWAROE[1,2,♥], ADITYA HIKMAT NUGRAHA[1], JURAIJ[1], ILHAM ANTARIKSA TASABARAMO[1]
[1]Department of Marine Science and Technology, Faculty of Fisheries and Marine Science, Institut Pertanian Bogor. IPB Dramaga Campus, Bogor 16680, West Java, Indonesia. Tel.: +62-251-8330970, Fax. +62-251-8330977, ♥email: mujizatk@gmail.com; mujizat@ipb.ac.id
[2]Surfactant and Bioenergy Research Centre (SBRC), Institut Pertanian Bogor. IPB Baranangsiang Campus, Jl. Pajajaran No.1 Bogor 16143, West Java, Indonesia

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Abstract. *Kawaroe M, Nugraha AD, Juraij, Tasabaramo IA. 2016. Identification of soybean genotypes adaptive and productive to acid soil agro-ecosystem. Biodiversitas 17: 585-591.* Seagrass is one of the coastal ecosystems in marine ecoregions of Indonesia that has very important ecological and economical functions. This study aimed to illustrate the diversity of seagrass ecosystems through its distribution, coverage, and density, in three marine ecoregions of Indonesia, namely Sunda Shelf/SHS (Bintan Island/SHS-B and the Seribu Islands/SHS-S), Sulawesi Sea/SS (Talaud Island), and Banda Sea/BS (Tanimbar Islands). The study was conducted at 16 stations in SHS, 20 stations in SS, and 30 stations in BS. A line transect method was used. Three line transects (length 50m) were deployed in each station perpendicular to the shoreline towards the sea with a distance of 20 meters between transect lines. In each line transect, quadrate transects were placed (0.5mx0.5m) along the line, alternating left and right line up to the edge. Species identification and seagrass density were calculated in each quadrate transect. Similarity indexes were calculated and analyzed between ecoregion on seagrass coverage and abundance through dendrogram graphic. Results showed that 10 species of seagrass were found in three marine ecoregions. In SHS-B, 10 species with a coverage cover of 61% were found and *Thalassia hemprichii* was of the highest abundance. In ShS-S, 6 species with a coverage cover of 37% were found and *Enhalus acoroides* species was of the highest abundance. In SS, 5 species with a coverage cover of 43% were found and *Cymodocea rotundata* was of the highest abundance. Finally, in BS, 7 species with coverage of 60% were found and *Thalassia hemprichii* was of the highest abundance. These results indicated that seagrass biodiversity found in 3 Indonesia marine ecoregions were still in a healthy condition. One of the implications of this healthy condition of seagrass was that the very important functions of seagrass as a habitat for economically important organisms and a food source for herbivores, particularly *Dugong dugong*, living in seagrass was still secured.

Key words: biodiversity, Indonesia, marine ecoregion, seagrass

INTRODUCTION

Twelve of 57 worldwide marine ecoregions are found in Indonesia (Huffard et al. 2012). All ecoregions are determined based on their biological diversity, including seagrass. Seagrass is part of an ecosystem found in coastal regions and the only flowering plant capable to live a submerged life in sea water (Kawaroe et al. 2016). Seagrass ecosystems have important roles as a source of primary productivity and a foraging and nursery ground for some marine biota (Erftemeijer et al. 1993; Christianen et al. 2014). In addition, seagrass plays a role in carbon cycle in the atmosphere (Duarte 2005; Kennedy et al. 2010).

Seagrass is so widespread in the world, but the highest biodiversity is found in the Indo-Pacific region, including Indonesia (Waycott et al. 2004). As a country with high biodiversity, Indonesia has 12 of 69 species of seagrass found in the world. Seagrass in Indonesia is found in coastal areas and small islands where it is able to live up to a depth of 40 meters. Seagrass lives in sand, sandy mud, mud, and rubble substrate. Based on the data validated by Indonesian Science Institute (2016), seagrass distribution in Indonesia reaches 25.742 ha in 29 locations around the country. Distribution and diversity of seagrass is found fairly throughout the coastal areas of Indonesia. Several studies have noted the presence of seagrass distribution but it remained unconnected with existing ecoregions.

Seagrass ecosystem conditions in some parts of Indonesia are found to be under threats from human activities such as tourism, ports, aquaculture, and sand mining. It was estimated that 58% seagrass ecosystems in the world has decreased the extents number (Waycott et al. 2009). According to Vo et al. (2013), seagrass bed areas in Indonesia are declined by about 30-40%, and the biggest damage of seagrass beds is found in Java Island. Pari Island is another place in Indonesia where seagrass is found to be reducing. This reduction occurs continuously every year as the effect of anthropogenic pressures (Kawaroe et al. 2008; Rustam 2014). The protection of seagrass ecosystems needs to be done immediately and this can be initiated by in-depth studies on the distribution and diversity. This study aimed to analyze the diversity of seagrass in three marine ecoregions of Indonesia including Sunda Shelf (Riau and the Seribu Islands), Sulawesi Sea (Talaud Island), and Banda Sea (Tanimbar Island). The diversity of seagrass was illustrated by its distribution, coverage percentage, density, and functions as well as threats to the existence of the seagrass ecosystems.

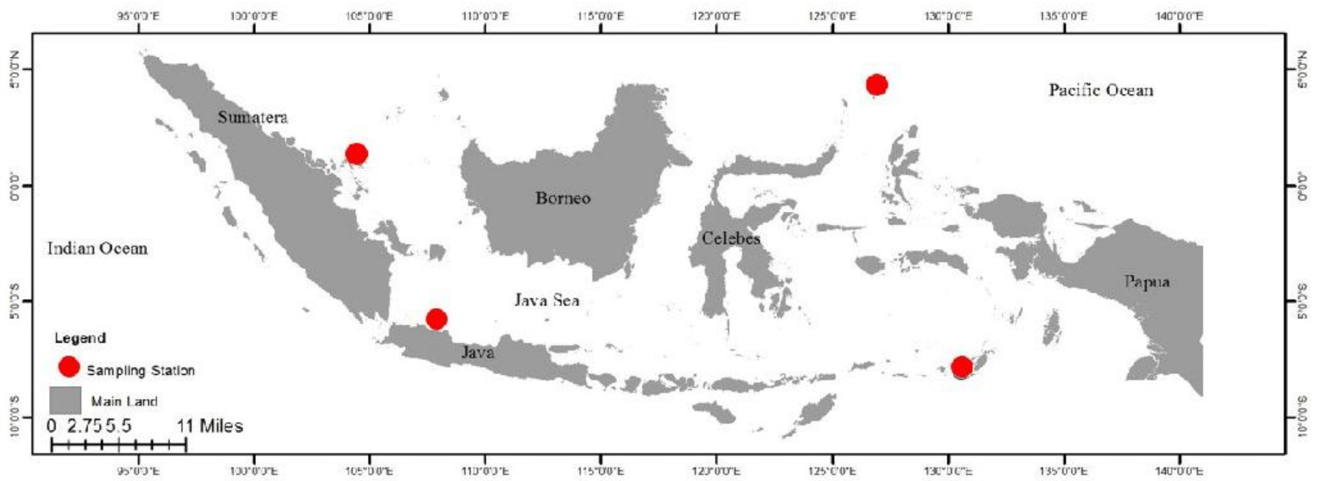

Figure 1. The research location of seagrass distribution in Indonesian marine ecoregion at the Lesser Sunda Shelf ecoregion, Sulawesi Marine Ecoregion and the Banda Sea Ecoregion

MATERIALS AND METHODS

Research locations

This research was conducted in 2015 in 3 marine ecoregions in Indonesia, namely Sunda Shelf represented by Riau Islands and Seribu Islands, Celebes Sea represented by Talaud Islands, and Banda Sea represented by Tanimbar Islands (Figure 1).

Seagrass observation methods

Observations were made using the line transect method when the lowest ebb occurred (English et al. 1997). Each study site was represented by five observation stations and each station consisted of three transect lines. The distance between each transect line was 50 meters. In each transect, a perpendicular line was drawn along 100 meters starting from the beginning of the shoreline where the seagrass was near perpendicular to the sea.

Seagrass density

Observations on seagrass density on each transect line were done by using squares sized 0.5mx0.5m (English et al. 1997; McKenzie and Yoshida 2009). Each square in transect lines was placed at a distance of 5 m. Seagrass density was calculating by the number of stands or shoots of any seagrass species that are found in the squares. Seagrass found on any squares were directly identified at the study sites from the shape of the leaves, rhizomes, flowers and fruits (McKenzie and Yoshida 2009; Waycott et al. 2004). The density of seagrass species was the total number of individual seagrass species in a unit area measured. Seagrass species density was determined by the following formula (English et al. 1997):

$$\mathbf{D} = \sum \frac{Ni}{A} \qquad \text{(1)}$$

Where:
D = Species density (shoot/m2)
N_i = Number of shoot of species-i
A = Sampling area (m^2)

Seagrass coverage

Seagrass coverage (%) was observed using Seagrass-watch method on the same square of seagrass density observations. Seagrass coverage of each seagrass species was calculated with the comparation to the picture available in each square on observation area (McKenzie and Yoshida 2009).

Seagrass diversity, evenness and dominance

Seagrass diversity was calculated using the following Shannon Wiener index (Odum 1983):

$$H' = -\sum \left(\frac{ni}{N}\right) \ln \left(\frac{ni}{N}\right) \qquad \text{(2)}$$

Where:
n_i = number of shoot in each species
N = total number of shoots

Table 1. Biodiversity Index Category (Odum 1983)

Biodiversity	Category
H’ < 2.0	Low
2.0 < H’ < 3.0	Moderate
H' ≥ 3.0	High

Seagrass similarity was calculated with the formula as follows (Odum 1983):

$$E = \frac{H'}{\ln S} \qquad \text{(3)}$$

Where:
E = Similarity index
H’ = Diversity index
S = number of species

Table 2. Similarity index category (Odum 1983)

Similarity	Category
0,00 < E < 0,50	Depressed community
0,50 < E < 0,75	Labile community
0,75 < E < 1,00	Stabile community

Seagrass dominant was calculated with the formula as follows (Odum 1983):

$$C = \sum\left(\frac{ni}{N}\right) \quad \text{.................................... (4)}$$

Where:
C = dominance index
n_i= number of shoots species
N = total number of individuals

Table 3. Dominant index category (Odum 1983)

Dominant	Category
0.00 < C < 0.50	Low
0.50 < C < 0.75	Moderate
0.75 < C < 1.00	High

Data analysis

Density and seagrass cover were analyzed using a cluster analysis. This analysis is a part of multivariate statistics, which was done to classify the seagrass in each region observed by its characteristics, namely density and seagrass cover.

RESULTS AND DISCUSSION

Species distribution and seagrass conditions

Results showed that in three marine ecoregions of Indonesia, 10 species of seagrass of two families were found (Table 4). These seagrass species were *Enhalus acoroides*, *Thalassia hemprichii*, *Halophila minor*, *H. ovalis*, *H. spinulosa*, *Cymodocea rotundata*, *C. serrulata*, *Halodule uninervis*, *H. pinifolia*, and *Syringodium isoetifolium.*

Seagrass species found throughout the ecoregions studied were *T. hemprichii, C. rotundata, H. uninervis and S. isoetifolium.* Four of these species were seagrasses that predominate in the Indo-Pacific region (Short et al. 2007). In addition, there was a seagrass species, *H. pinifolia* that was only found in Riau Islands waters. According to UNEP (2008) *H. pinifolia* seagrass was considered as a pioneer seagrass species and one of its distribution areas was Riau Islands. This seagrass species was also found in some coastal areas of Malaysia (Bujang et al. 2006) and Singapore (Yaakub et al. 2013). Geographically, the coastal Regions of Malaysia and Singapore have a location adjacent to Riau Islands and it is a Sunda Shelf ecoregion. Therefore, the similarity of seagrass species found in these three locations was the evidence of similar environmental conditions the regions shared. Most seagrass species was found in Riau Islands and Tanimbar Islands. This was presumably because of the fact that these regions were adjacent to the open sea. Riau Islands are close to the South China Sea and Tanimbar Islands are located adjacent to Arafuru Sea. The existence of strong current in locations adjacent to high seas allows the connectivity process in biodiversity (Chiu et al. 2013).

Table 4. Seagrass species distribution in three marine ecoregions (represented by 4 islands) of Indonesia

Family/Species	Sunda Shelf		Sulawesi Sea	Banda Sea
	Riau Islands	Seribu Islands	Talaud Islands	Tanimbar Islands
Hydrocharitaceae				
Enhalus acoroides	+	+		+
Thalassia hemprichii	+	+	+	+
Halophila minor	+			+
H. ovalis	+		+	+
H. spinulosa	+			
Potamogetonaceae				
Cymodocea rotundata	+	+	+	+
C. serrulata	+	+		
Halodule uninervis	+	+	+	+
H. pinifolia	+			
Syringodium isoetifolium	+	+	+	+

Note: + : found

Seagrass cover found in 4 islands of 3 marine ecoregions in Indonesia was different (Figure 2). Seagrass cover in Riau Islands waters was 61%, Seribu Islands 37%, Talaud Islands 43%, and Tanimbar Islands 60%. The differences in seagrass covers were caused by several factors including seagrass topography, physical and chemical water condition, coastal community activities around the seagrass, and distribution of seagrass species (UNEP 2008). Another factor that could affect the distribution of seagrass was predation of seagrass by biota associations (Heck and Valentine 2006). Based on the obtained seagrass cover, Riau Islands and Tanimbar Islands had seagrass cover higher than did the other two islands. The lowest seagrass cover was found in Seribu Islands. The close location of Seribu Islands to Jakarta Bay was presumably the cause of this. There are 13 rivers flowing into the Gulf of Jakarta with high enough pollutant loads to affect the biodiversity of coastal ecosystems in the surrounding waters of Jakarta Bay. According to Ambo-Rappe (2014), if the location of seagrass ecosystems was very close to the mainland it had the potential to receive the negative effects of anthropogenic activities from that mainland. In addition to the base of substrate and water conditions, number of residents in a region, which was correlated with anthropogenic stress, was another factor affecting seagrass cover and distribution. (Campbell and McKenzie 2004; Waycott et al. 2005).

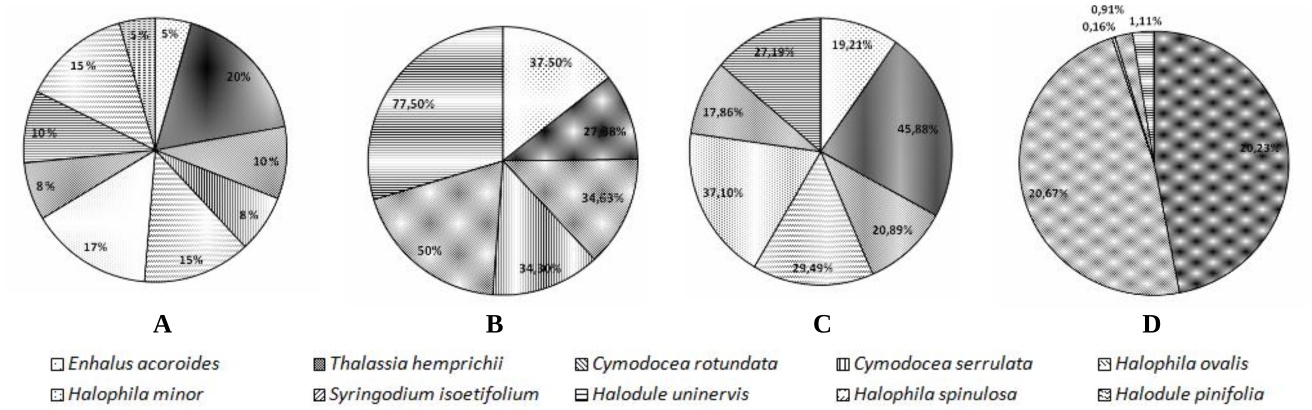

Figure 2. Seagrass cover (%) at 4 islands (3 marine ecoregions in Indonesia): A. Riau Islands, B. Seribu Islands, C. Talaud Islands, and D. Tanimbar Islands.

It was shown from the seagrass cover in each species (Figure 2) that in Riau Islands, *T. hemprichii* was the highest (20%) followed by *H minor* (17%) while in Seribu Islands, *H. uninervis* was the highest (77.5%) followed by *E. acoroides* (37.5 %). Talaud Islands had *C. rotundata* and *T. hemprichii* with the highest cover percentage of 20.67 and 20.23%, respectively. In *Tanimbar* Islands, *T. hemprichii* and *H minor* were found by 45.88and 37.10%, respectively. *T. hemprichii* was the species found to have a high coverage in all locations. Seagrass species had a very wide distribution in Indonesian waters (UNEP 2008) and this was suspected to be caused by its cosmopolitan nature in the Indo-Pacific region and its ability to adapt to the environment (Klumpp et al. 1993). In addition to *T. hemprichii, C. rotundata* was found to have high coverage as it could tolerate a wide range of water conditions (Tomascik 1997).

The highest density of seagrass species was found in Riau Islands and the lowest one in Talaud Islands (Table 5). It was suspected that the finding caused the high density of seagrass in Riau Islands that the substrate in the region was sandy clay that was a suitable substrate for seagrasses to grow. This condition was different from that in the other three locations where sand was the dominant substrate. Substrate is one of the important factors affecting the density of seagrass (Kaewsrikhaw and Prathep 2014).

The number of individual seagrass species found in a region was affected by diversity, uniformity and dominance of seagrass (Figure 3). Results showed that the diversity of seagrass in three Indonesian marine ecoregions belonged to medium and low categories. Riau Islands and Tanimbar Islands had a diversity index of seagrass of medium category while those of Seribu Islands and Talaud Islands belonged to low category. This might be caused by the finding that the uniformity of seagrass in three marine ecoregions belonged to the instability category indicating that the condition of the waters was under threats, both from natural factors and human activities. There was highly dominating species found in Talaud Islands. This indicated that certain types of seagrass had a tendency to dominate and have a wide distribution in the area. *C. rotundata* and *T. hemprichii* segrasses had the most extensive distribution and were often found in Talaud Islands. According to Hemminga and Duarte (2000), seagrass, which had extensive deployment, had a high adaptability so that it could grow well in different habitat types with various environmental conditions.

Table 5. Seagrass species density in three marine ecoregions (four islands) in Indonesia

Family/Species	**Seagrass density (ind/m^2)**			
	Riau Islands	**Seribu Islands**	**Talaud Islands**	**Tanimbar Islands**
Hydrocharitaceae				
Enhalus acoroides	62±16.83	372±63.04	0	45±06.65
Thalassia hemprichii	417±17.37	608±50.91	123±13.02	358±26.80
Halophila minor	280±12.00	0	0	161±9.97
H. ovalis	350±10.87	0	2	191±2.55
H. spinulosa	244±43.00	0	0	0
Potamogetonaceae				
Cymodocea rotundata	166±7.07	844±178.19	131±22.23	150±2.06
C. serrulata	120±5.37	784±339.41	0	0
Halodule uninervis	222±17.45	0	16±1.7	323±25.85
H. pinifolia	112±10.09	0	0	0
Syringodium isoetifolium	318±17.82	612±32.75	11±2.8	430±2.64

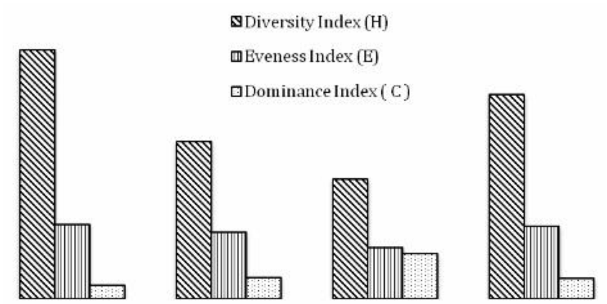

Figure 3. Diversity (H'), evenness (E), and dominance (C) of seagrass at three marine ecoregions in Indonesia

Results of cluster analysis based on the density showed that there were large seagrass ecosystems. The first group consisted of Talaud Islands (Sulawesi Marine Ecoregion) and Seribu Islands (Sunda Shelf Ecoregion) (Figure 4). The second group with the highest similarity scores consisted of Riau Islands (Sunda Shelf) and Tanimbar Islands (Banda Sea Ecoregion). Results of a cluster analysis showed that the groups with the highest percentage of seagrass cover were Tanimbar Islands and Talaud Islands as the first group, Riau Islands as the second group and Seribu Islands as the third group. It was also shown that the conditions of seagrass ecosystems, represented by both density and seagrass cover percentage, were influenced by environmental factors such as habitat, topography, type of substrate, distribution of seagrass species, and human activities around the seagrass (UNEP 2008; Gonzalez-Correa et al. 2007; Waycott et al. 2005).

Utilization of and threats to seagrass ecosystems

Seagrass ecosystem have very important role both ecologically and economically. Considering that role then it needs to be protected from threats that could undermine its existence and reduce its functions. Threats that can damage seagrass can be caused by human activities and events that occur naturally. Based on observations in the field, the important role and the threat contained in seagrass ecosystems in some areas located in three ecoregions Indonesia are presented in Table 6.

Seagrass ecosystems in three ecoregions in Indonesia have a role as catchment area of biota, which can be used, as a food source for coastal communities. It shows that seagrass plays a role as a feeding and nursery area ground making many-associated biota live in seagrass. The number of biota living in seagrass ecosystems indicates that these ecosystems bring benefits as a source of food security for coastal communities (Cullen-Unsworth et al. 2013). Most people use gears such as nets (gill net), spear gun or a hand to catch organisms in seagrass and consume them as food. If the catch result is in excess, it is sold to the public. The majority of captured organisms are squid, gastropods, fish and shellfish.

Another important point is the role of seagrass as a feeding area for *Dugong dugong*. Dugong is one of the marine herbivorous mammals, which have a very high dependence on seagrass (Preen 1995). Dugongs like high-density seagrass areas (Bujang and Mutaharah 2002), and they are founding Riau Islands (Sunda Shelf) and Tanimbar Islands (Banda Sea). *Halophila* sp., *Halodule* sp., and *Syringodium* sp. are seagrass species favored by Dugong (Heinsohn and Birch 1972). These seagrass species are very common to be found in Riau Islands and Tanimbar Islands.

The threats to seagrass in Seribu Islands (Sunda Shelf) were mostly derived from human activities. Seribu Islands region is a tourist destination and located near the Bay of Jakarta making it prone to conditions that threaten the sustainability of seagrass ecosystems. Some of seagrass ecosystems found in Riau Islands are now considered as protected areas and this has made seagrass remain in good condition and alive. Meanwhile, seagrass at Talaud Islands (Celebes Sea) and Tanimbar Islands (Banda Sea) tended to be free from threats from human activities as human population in the two islands was still low. This condition

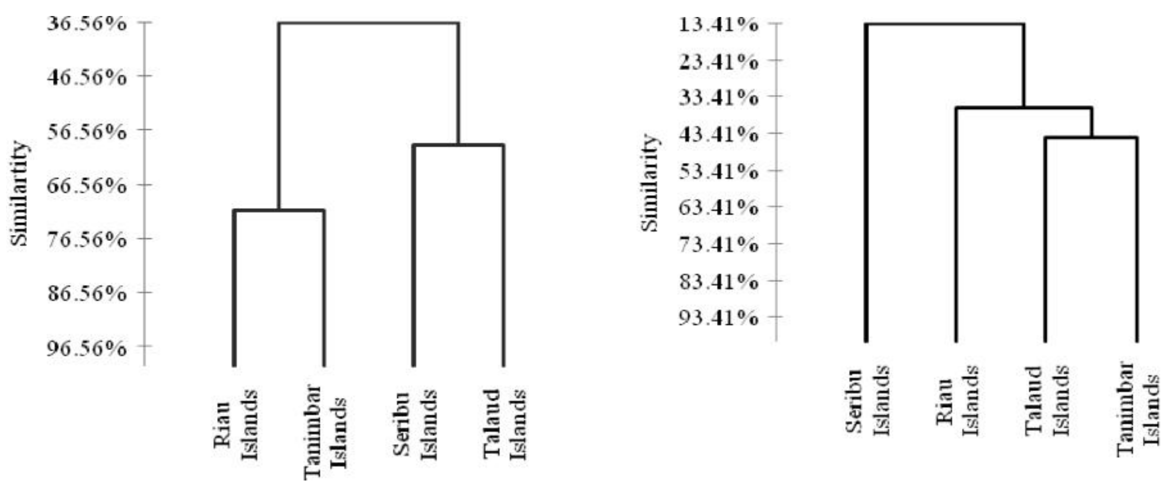

Figure 4. Dendogram of seagrass cluster analysis in three ecoregions of Indonesia (4 islands) based on the density (left), the cover percentage of seagrass (right)

Table 6. The important role of and the threats to seagrass in three ecoregions (4 Islands) in Indonesia

Ecoregion/Island/ Location	Habitat Association	The important role of seagrass	Threat	
			Human activity	Natural
Sunda Shelf (Riau Islands): Penggudang, Busung	Inter-tidal	• Habitat for gastropods, bivalves, fish, sea cucumber, echinoderms • Feeding ground for dugongs • Small-scale fisheries and traditional fishing, recreation area • Some areas are used for seagrass conservation	• Oil spill • Ocean pollution	• Sedimentation
Sunda Shelf (Seribu Islands): Pramuka Island, Pari Island	Inter-tidal	• Habitat for gastropods, bivalves, fish, sea cucumber, echinoderms • Capture fisheries and small-scale traditional learning area • Recreation area	• Ocean pollution • Reclamation • Transportation • Tourism	• Macroalgae invation • Lowest ebb • Transportation
Sulawesi Sea (Talaud Islands): Karokotan Islands	Inter-tidal	• Habitat for gastropods, bivalves, fish, sea cucumber, echinoderms • Capture and small-scale traditional fisheries	• Transportation	• High Wave
Banda Sea (Tanimbar Islands): Yamdena Island, Selaru Island, Larat Island	Reef flat	• Habitat for gastropods, bivalves, fish, sea cucumber, echinoderms • Feeding Ground for Dugong and turtle • Capture fisheries and small-scale traditional • Local wisdom "SASI" to protect seagrass.	• Marine culture • Transportation	• Sedimentation • Lowest ebb

was also supported by the local knowledge on local community applied in managing marine resources. One of these local wisdoms was called SASI. Closing fishing access for a certain period of time did management with SASI system. During this closure public were forbidden to take biota that live in the seagrass. This aimed to provide opportunity for organisms to reproduce and maintain the survival of organisms that live in the seagrass. People who violated SASI would be socially punished. Communities were allowed to take biota found in seagrass when SASI was revoked.

To summary, there were 10 species of seagrass found in three marine ecoregions of Indonesia (Sunda Shelf, Sulawesi Sea, and Banda Sea). Distribution and seagrass density was highest (61%) in Riau Islands waters (Sunda Shelf Ecoregion) and was dominated by *T. hemprichii*. Meanwhile, the value of seagrass cover in Tanimbar Islands was 60%, in Talaud Islands43%, and in Seribu Islands 37%. Based on their seagrass density, these marine ecoregions could be put in two groups namely Talaud Islands (Sulawesi Marine Ecoregion) and Seribu Islands (Sunda Shelf Ecoregion) as group one and Riau Islands (Sunda Shelf Ecoregion) and Tanimbar Islands (Banda Ecoregion) as group two. Meanwhile, based on the lack of coverage three groups were obtained, namely Tanimbar Islands and Talaud Islands as the first group, Riau Islands as the second group, and Seribu Islands as the third group. Marine ecoregions in Indonesia did not really affect seagrass, but the magnitude of the threat from human activities was the major cause of damage to the aquatic environment and substrate conditions. Seagrass had a very important role in maintaining the survival of some aquatic biota. Some predators could be used as a food source for coastal communities. Therefore, seagrass brought a very important benefit as a direct positive impact to the coastal communities in the territory of Indonesia.

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