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SEAGRASS CONDITION AT SOME SMALL ISLANDS IN THE TAKA BONERATE NATIONAL MARINE PARK, SOUTH SULAWESI INDONESIA

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ABSTRACT

The assessment of seagrass bed condition in Indonesia still refers to the Decree of the State Minister for the Environment (KMNLH) No. 200 of 2004, which considers only one variable, namely the percentage of seagrass cover. To assess the seagrass beds condition to be more in-depth and meaningful, it is necessary to consider the addition of several variables, such as the biotic variables (seagrass species diversity including macroalgae and macro-benthos components) as well as the abiotic variables (reef flat areas and the substrate components). The purpose of this study is to determine the seagrass beds condition in several small islands in the Taka Bonerate National Marine Park by considering the additional analysis using both biotic and abiotic variables as mentioned above. The methodology used in this study is a combination of the use of the standard seagrass transect method, interpretation of satellite imagery related to the seagrass bottom habitat area, and its components on the reef flat of a particular island, as well as weighting and scoring based on those considered additional variables. By applying the criteria in the method, the seagrass bed conditions were then classified into three categories, namely seagrass in good, moderate, and unfavorable conditions, respectively. The results of the total score assessment on several small islands in Taka Bonerate Islands show that the seagrass bed in Latondu Besar Island is in good conditions with the highest score of (316) compared to Tarupa Besar, Jinato, Rajuni Kecil, and Tinabo Besar Islands with an average score of (173). The results of this study indicate that the assessment of seagrass conditions is more meaningful in terms of seagrass ecology than based on seagrass cover alone. However, this study requires a lot of validation for its application in assessing the condition of seagrass beds in other islands in Indonesia.

Keywords: Seagrass, biotic and abiotic variables, score, condition, Taka Bonerate.

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INTRODUCTION

Seagrasses are higher flowering plants (*Angiosperms*), which are fully adapted in the shallow marine (saltwater) environment such as in estuarine, and they can carry out the generative cycle in a submerged state (Wood, *et al*., 1969; Papenbrock, 2012). Similar to higher plants on land, all seagrasses are monocotyledonous plants that have roots, rhizomes, leaves, flowers, and fruit (Thomlinson, 1974). These plants can develop to form a wide expanse in the tidal and subtidal zone to form a large area commonly called a seagrass meadow or seagrass bed that can be either made up of a single (monospecific) or mixed (heterospecific) species (Nienhuis *et al*., 1989; Vermaat *et al*., 1995), in which the size of seagrass beds is large enough to be seen from space or detected by a satellite sensor. The reciprocal relationship between one type of biota to another biota and its environment (abiotic components) in certain seagrass beds is called a seagrass ecosystem (den Hartog, 1970; Erftemeyer & Lewis III, 2006).

There are 3 unique tropical ecosystems in the coastal zone of Indonesia, namely mangroves, seagrasses, and coral reefs. Each ecosystem has very high productivity that is higher than the rain forest ecosystems (Anon, 2001). Therefore, they provide goods and environmental services to the local community living nearby (Hughes & Stachowics, 2004) and use there as a source of livelihood (Sjafrie *et al*., 2021 & Furkon *et al*., 2020). The tropical seagrass ecosystem, which is located between the mangrove and coral ecosystems regulates the diversity of flora and fauna in coastal areas (Phinn, *et al*., 2008). The ecology and economic function of seagrass strongly support the fisheries sector because of its role as spawning, nursery, and feeding ground for various species of fishes, crustaceans (shrimps, crabs), mollusks (bivalves, gastropods), echinoderms (sea cucumber, sea urchin), etc. (Erftemeijer & Lewis III., 2006; Holmer *et al*., 2008), including protected marine animals such as dugongs and green turtles (McKenzie & Cambell, 2002).

The seagrass ecosystem also plays a significant role in recycling various nutrients and rare elements in the marine environment then utilized by certain biota. Thus, it forms an important complex food chain network (Fortes,1989). Seagrass is important in trapping and stabilizing sediments so that the waters become clearer, which supports the important requirement of coral reef lives (Erftemeijer & Lewis III, 2006; McKenzie, 2007). Furthermore, seagrass, mangroves, and brackish swamps in the coastal areas are capable to store a large amount of carbon in the sediments known as blue carbon. It is estimated that one square meter of seagrass bed can sequest 83 g carbon per year, the same amount of carbon emitted by a car traveling around 6,212 km, which is 55% more effective than terrestrial forests (Nellemann *et al*., 2009).

According to the calculation of limited data on the economic valuation of the seagrass ecosystem shows a value of US$ 2.300 ha-1year-1 consisting of contributions from the tourism, fisheries sectors, and aesthetic value, respectively for seagrass beds in Bintan Island in 2006 (Dirhamsyah, 2007). The newest data of the total economic value of seagrass (Direct use+Indirect use+Option+Existence values) in Berakit Village, Bintan Regency, Riau Islands Province is Rp (Indonesian Rupiah) 6.486 billion/year (Agustina *et al*. 2015). Those values are too low when compared to data calculated by Erftemeijer & Lewis III (2006), where a conservative calculation of the economic value of goods and services provided by the seagrass ecosystem is US$19,000 ha-1.year-1.

On the other hand, although seagrass beds provided goods and environmental services, seagrass in the world continuously experienced various threats that caused a decline in both quality and quantity for the past 2 decades, including in Indonesia. The loss of seagrass areas in the world is estimated to be around 33,000 km^2. Now, the seagrass area is around 177,000 km2. The damage and loss of seagrass are due to the impact of human activities, either directly or indirectly (Orth, *et al*., 2006, Waycott, *et al*., 2009). In more detail, the damage to seagrass is caused by the increase in water turbidity that is caused by dredging of the seabed for making shipping lanes and port entrances, sand mining for buildings, and filling the beaches for reclamation areas (Erftemeijer & lewis, 2006). ii) The eutrophication process is caused by an excessive supply of nutrients (usually from land) that enters the seagrass ecosystem, causing the explosion of macroalgae (seaweed) and microalgae (phytoplankton) populations, which causes competition for light and nutrients. The possible damage of seagrass ecosystems due to eutrophication has been going on for decades (Cardoso *et al*., 2004). iii) Another significant impact is climate change, which includes an increase in air temperature, sea level, disturbances from strong winds and waves (cyclone, typhoon), excessive ultraviolet light exposure, increasing concentrations of carbon dioxide which lead to increasing ocean's pH, and ocean currents are factors that can damage seagrass beds, their resilience, and adaptation (Waycott *et al*., 2007). iv) The local damage to seagrass beds can also be caused by fishing boat anchors and propellers as well as garbage problems.

Seagrass beds in the coastal areas of Indonesia are an important ecosystem that faces various global and local threats as mentioned before, so this ecosystem deserves serious attention. Therefore, the condition of seagrass in all coastal areas of Indonesia needs to be assessed, mapped, monitored, evaluated, and managed sustainably. Efforts towards this have been made by the Indonesian Ministry of Environment (KMNLH) by issuing ministerial decree No. 200 in 2004 on assessment of the condition of Indonesian seagrasses based on one simple variable only, namely seagrass cover, while another assessment method is still not available. However, considering that seagrass ecosystems are complex ecosystems, the assessment of seagrass conditions needs to be expanded by adding other biotic variables (species diversity of seagrass, macroalgae, and macrobenthos) as well as an abiotic variable (reef flat substrates). This study aims to develop a new seagrass condition assessment by adding more biotic and abiotic variables to get more deepen understanding of the seagrass dynamics in some small Islands of the Taka Bonerate marine park.

METHODOLOGY

Study Site

Taka Bonerate National Park is one of the marine national parks in Indonesia that has been established on the decree of the Forestry Minister of Republic of Indonesia No. 280/Kpts-II/1992 and has been acknowledged by UNESCO as a World Heritage site since 2005. This national park is located at the coordinates 6°41'S and 121°9'E which is administratively located on the of the waters of Selayar Island, district of Taka Bonerate, Selayar Archipelago Regency, South Sulawesi Province, with an area of about 530,765 ha or 5.307 km^2 (Kecamatan Taka Bonerate Dalam Angka, 2019) consists of atolls, lagoons and small islands with a vast coral reef.

The study was held in May-June 2019 at the site of the Tarupa Besar Island, Jinato, Latondu Besar, Rajuni Kecil, and Tinabo Besar. The coordinates of each site as presented in Table 1 and Figure 1.

Seagrass and Megabenthic Sampling

Data were collected in two stations of each island, except for Rajuni Kecil and Tinabo Besar Islands which were only done in one station due to lack of time available. Data from each station were gathered in three transect lines. The length of each transect line is 100 m from the coastline and the distance between

Table 1. Sites coordinate at small Islands

Islands	Site	Coordinate (S/E)	
Tarupa Besar	01	-6.49684	121.13377
	02	-6.49485	121.13655
Jinato	03	-6.76289	120.96694
	04	-6.75130	120.96794
Latondu Besar	05	-6.50214	120.98394
	06	-6.5044	120.98558
Rajuni Kecil	07	-6.54596	120.99787
Tinabo Besar	08	-6.56688	121.09983

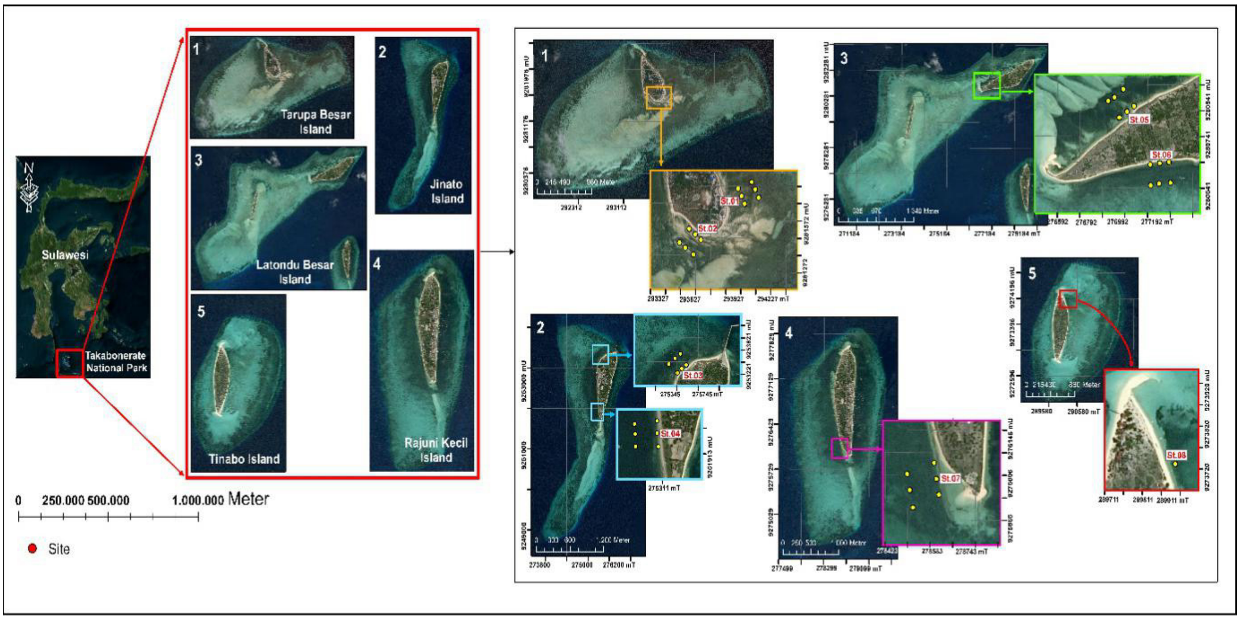

Figure 1. Study site at 5 small islands in the National Park of Taka Bonerate - South Sulawesi, Indonesia.

transects is 50 m so that the area of observation is one hectare. Quadrat 50x50 cm is placed at intervals of 10 m along the line transect. In each frame, observations of seagrass such as species diversity, percentage of seagrass cover, dominant species, macroalgae, epiphytes, and substrates were carried out (Short *et al*., 2001; Short *et al*., 2004; McKenzie, *et al*., 2003 & Rahmawati, *et al*., 2017). The existence of mega benthos such as gastropods, bivalves, and Echinodermata was also assessed. All living benthic specimens found within the quadrat were collected and preserved using alcohol 70%. Samples were identified to lowest taxa based on references by Abbott & Dance (1990), Poutiers (1998), Dharma (2005), Clark & Rowe (1975).

Determination of basic types of substrates (mud, muddy sand, sandy and corals fragment) is using the megascopic. Category of seagrass cover is based on the percentage of cover seagrass 'very dense ' (75-100) %, 'dense ' (50-75) %, 'medium ' (25-50) % and 'rare ' < = 25 (English *et al*., 1994 & Rahmawati *et al*., 2017). The average of data from all transects (33 frames) was calculated to represent the data of each station of the observed island. Data between each island were analyzed using the Similarity Index (SI) to see similarities in species diversity (Clarke & Warwick, 2001).

Benthic Habitat

Benthic habitat such as seagrass, sand, macroalgae, hard coral was identified using Sentinel-2 satellite imagery level 1 C record 2018 August with 10 m spatial resolution and multispectral bands which are essential for identifying benthic habitat objects (Green *et al*., 2000; Hedley *et al*., 2016). Image processing analysis consists of atmospheric correction, sun-glint correction, water column correction, masking image, image classification, and accuracy assessment. The last process of the image was grouping the pixel value into defined benthic habitat classes (seagrass, macroalgae, sand, hard coral, and reef flat). The Maximum Likelihood Algorithm was chosen regarding the availability of classification sample and normal distribution of histogram in an image used. The process of image analysis in the calculation of the area of benthic habitat objects is strongly influenced by tidal conditions of water, so it is necessary to check each object in the field (Sea truth).

To determine the relationship between each area of benthic habitat such as (seagrass vs reef flat), (seagrass vs sand), (seagrass vs macroalgae), and (seagrass vs hard coral) a simple statistical analysis was carried out using the Excel program.

Seagrass Condition

Seagrass conditions of small islands could be divided into two components namely biotic (biological value) and non-biotic (ecological value). The non-biotic component is referred to any information that deals with the basic condition and variety of living organisms. It is significant to evaluate the seagrass condition not only referring to the biotic but also non-biotic variables. To give the comprehension of the important value of each component, the weighting approach on each variable with both objective and subjective manner prone to the chance or probability to affect seagrass condition in a certain area.

Determination of the 'range' for each variable, both biotic and non-biotic (eg extent of seagrass, macroalgae, sand, hard coral, and reef flat) is based on the analysis of satellite imagery data. Based on the result of data from the image analysis of each habitat object, such as the area of seagrass, macroalgae, sand, hard coral, and the area of reef flat on each island were classified into four ranges. For example, the calculate of the seagrass area of each island were Tarupa Besar (248.9 ha), Jinato (224.9 ha), Latondu Besar (721.47 a), Rajuni Kecil 146.1 ha) and Tinabo Besar (63 ha) and then classified into four ranges (63-227) ha, (228-392) ha, (393-557) ha, and (558-722) ha. This calculates also applied to macroalgae, sand, and reef flats range. The 'range' for the variable percentage of seagrass cover, the number of seagrass species, and the number of megabenthic species were based on the results of field data of each island.

Giving the proportion of weight (%) for each biotic or non-biotic variable by considering the possibility that the variables affect seagrass conditions. The greater the weighting (%), the more influential it is, so a higher value is given (Vinh, *et al*., 2008 & Hartoko, *et al*., 2014). The total score is the result of multiplying the 'value' (a) with the weight (b) of each variable (Arifin *et al*., 2014). Determination of seagrass conditions was classified into 'good' (257-319), 'moderate' (194-256), 'poor' (131-193), based on the total score of biotic and non-biotic variables on each island. The Metrix table of each variable was presented as on Table 2.

RESULTS AND DISCUSSION

The environment of Small Island

Based on several variables environment in some of the small islands, Latondu Besar Island is one of the Islands that have been supported by environmental characteristics (Table 3). Likewise, in the large reef flat area, it is possible to habitat potential growth for seagrass meadow and the existence of it also gives unique characteristics to the habitat of many animals, such as mollusks and crustaceans (Coen & Heck, 1991). It also has endemic vertebrates is *Anemon* (red Corn-common name) or *Entacnea* (scientific name) (Hartoko *et al*., 2014). Sparse population suggests it can

Table 2. Biotic and abiotic variables of the seagrass conditions of the small Islands

No.	Variables	Range*	Value** a	Weight (%) b	Score*** (a)x(b)	Source/Reference
	BIOTIC					
1	Seagrass extent (ha)	63-227	1	18	18	Image analysis, 2019
		228-392	2		36	
		393-557	3		54	
		558-722	4		72	
2	Persentage seagrass cover (%)	<=25	1	20	20	Field data, 2019 & Rahmawati et al., 2017
		26-50	2		40	
		51-75	3		60	
		76-100	4		80	
3	Number of seagrass species (indv)	<=4	1	17	17	Field data, 2019
		5-8	2		24	
		9-12	3		51	
		>=12	4		68	
4	Number of megabenthic species (indv)	8-11 1	15	15		Field data, 2019
		12-15	2		30	
		16-19	3		45	
		20-23	4		60	
5	Macroalgae extent (ha)	62-77	1	8	8	Image analysis, 2019
		45-61	2		16	
		28-44	3		24	
		11-27	4		32	
	ABIOTIC:					
6	Sand extent (ha)	41-233	1	8	8	Image analysis, 2019
		234-426	2		16	
		427-619 3			24	
		520-812 4			36	
7	Reef flat extent (ha)	242-768	1	14	14	Image analysis, 2019
		769-1.295	2		28	
		1.296-1.822	3		42	
		1.823-2.349	4		56	

Note * (field data) and image analysis
** value class based on Hartoko, 2014 (1=poor, 2=fair, 3=good, 4=very good)
*** score total each Island = ∑ (a)x(b), seagrass condition classify:
good (257-319), moderate (194-256), poor (131-193).

minimize the anthropogenic impact on the seagrass meadow as boating daily routine activities including anchoring (Francour *et al*., 1999) and propeller scar (Bell *et al*., 2002; Burfeind, 2006).

Based on a simple linear regression analysis software excel between the variable seagrass extent (Y) and reef flat extent (X), a significant relationship was found (R^2 = 0.99), (Figure 2 a, b, c, d) this

Table 3. Environment Characteristic in Small Islands

	Small Islands				
	Tarupa Besar	**Jinato**	**Latondu Besar**	**Rajuni Kecil**	**Tinabo Besar**
Parameters/Variables:					
-Island extant (ha)	19.4	50.3	98.8	43.3	17.5
-Coastline (m)	1,818	3,681	5,612	3,428	2,161
-Population	1,384	1,360	940	2,105	-
-Reef flat extent (ha)	585.5	593.8	1,889.3	370.3	244.01
-Seagrass extent (ha)	248.9	224.96	721.47	146.12	63.3
-Sand extent (ha)	149.5	123.5	809.6	41.2	83.8
-Macroalgae extent (ha)	32.4	12.2	76.9	11.2	13.1
-Area of hard coral (ha)	154.8	233.1	281.2	171.8	83.8
-Waters depth (cm):	52-86	93-145	64-89	111-143	81-106

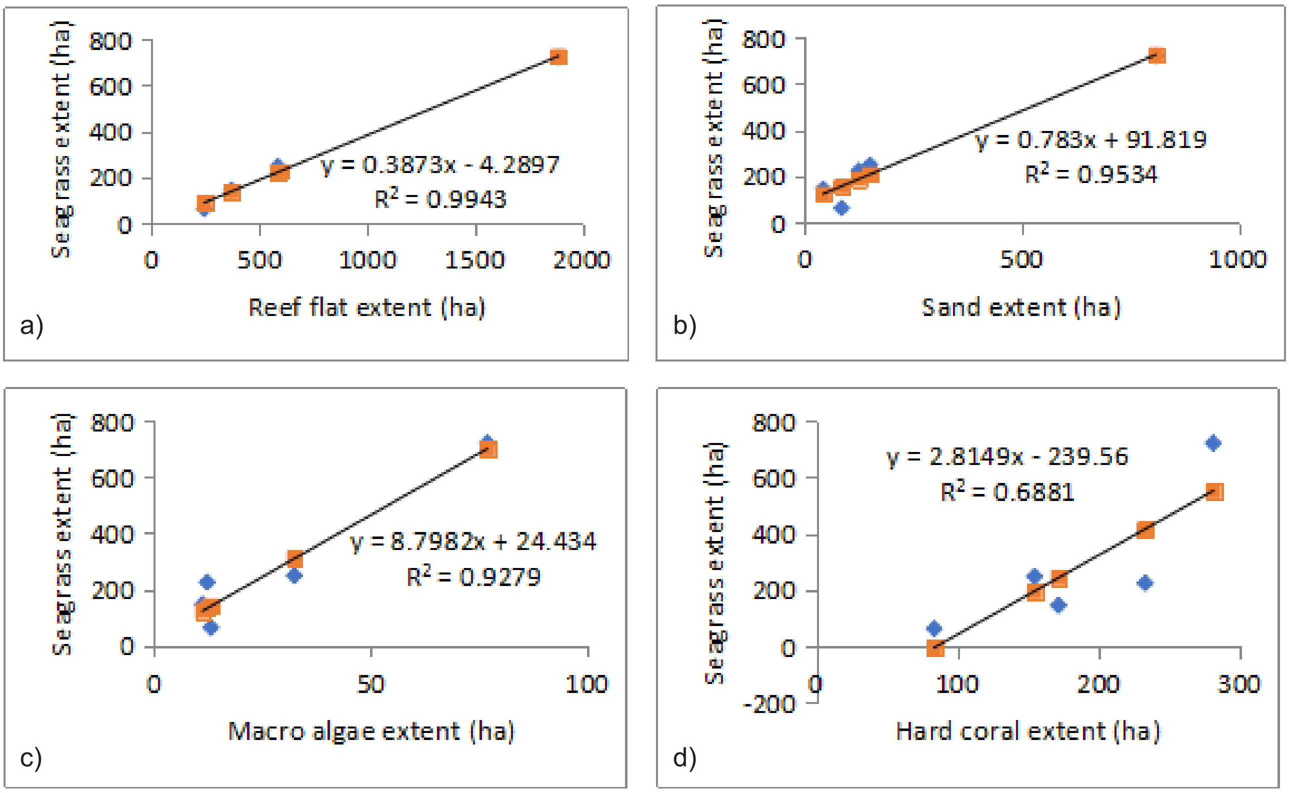

Figure 2. Regression linear some of the habitat benthic: seagrass extent vs (reef flat, sand, macroalgae, and hard coral extent). a)Seagrass vs reef flat; b) Seagrass vs sand; c) Seagrass vs macroalgae; d) Seagrass vs hard coral.

mean reef flat extent has influence significant on the extent of seagrass compared with the extent of sand, macroalgae and hard coral.

Based on Environment Characteristic (Table 3) was knowing the total area of each habitat benthic. Total habitat covers at the five small islands are seagrass extent (1,404.8 ha), sandy (1,207.8 ha), macro-algae (145.8 ha), and hard coral (924.6 ha) and proportional of habitats benthic as presented in Figure 3. There is something interesting about the proportion of benthic cover habitat for the higher hard coral (46%) at the Rajuni Kecil compare with another island (Tarupa Besar, Jinato, Latondu Besar, and Tinabo Besar), this needs to be studied more deeply related to that high of hard coral on the island.

Community structure of seagrass

Seagrass species diversity

The diversity of seagrass species in Indonesian

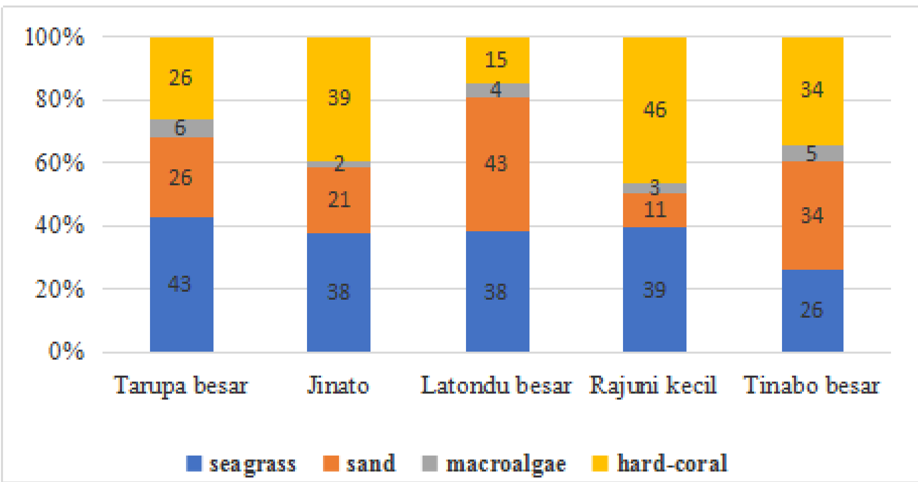

Figure 3. Proportional of habitat benthic cover each small islands.

Table 3. Environment Characteristic in Small Islands

Name of Island	Number of species	Ea	Th	Cr	Cs	Si	Hu	Hp	Ho
Tarupa Besar	4	-	+++	+++	-	-	-	+	+
Jinato	5	++	+++	++	+	+	-	-	-
Latondu Besar	5	-	+++	+	-	+	+	-	+
Rajuni Kecil	5	+	+++	++	+	++	-	-	-
Tinabo Besar	5	-	+++	++	+	+	-	-	+

Remark:+ = Present, - = Absent (+++, ++, + = dominant -> less domint)
EA (*Enhalus acoroides*), TH (*Thalassia hemprichii*), CR (*Cymodocea rotundata*), CS (*Cymodocea serrulata*), SI (*Siringodium isoetifolium*), HP (*Halodule pinifolia*), HO (*Halophila ovalis*).

waters found 12 species, including *Enhalus acoroides* (*Ea*), *Halophila decipiens* (*Hd*), *Halophila minor* (*Hm*), *Halophila ovalis* (*Ho*), *Halophila spinulosa* (*Hs*), *Thalassia hemprichii* (*Th*), *Cymodocea rotundata* (*Cr*), *Cymodocea serrulata* (*Cs*), *Halodule pinifolia* (*Hp*), *Halodule uninervis* (*Hu*), *Syringodium isoetifolium* (*Si*), and *Thalassodendron ciliatum* (*Tc*) (Green & Short, 2003) with the found species *Halophila sulawesi Kuo* (*Hsl*) (Kuo, 2007) into 13 species. Seagrass species in Kep. Taka Bonerate has been reported total of 8 species including *Halophila ovalis* (*Ho*), *Thalassia hemprichii* (*Th*), *Cymodocea rotundata* (*Cr*), *Cymodocea serrulata* (*Cs*), *Halodule pinifolia* (*Hp*), *Halodule uninervis* (*Hu*), Syringodium isoetifolium (*Si*), and Enhalus acoroides (*Ea*). Seagrass meadows form multi-specific meadows consisting of 4-5 species on each small island (Table 4). Species diversity is currently on decline compared to 10 species of seagrass, including *Halophila decipiens* (*Hd*), *Halophila minor* (*Hm*), *Halophila ovalis* (*Ho*), *Thalassia hemprichii* (*Th*), *Cymodocea rotundata* (*Cr*), *Cymodocea serrulata* (*Cs*), *Halodule pinifolia* (*Hp*), *Halodule uninervis* (*Hu*), *Syringodium isoetifolium* (*Si*), and *Thalassodendron ciliatum* (*Tc*) (Kuriandewa *et al*., in Green & Short, 2003).

Table 4. Seagrass composition in each Islands of the study area

Name of Island	Number of species	Ea	Th	Cr	Cs	Si	Hu	Hp	Ho
Tarupa Besar	4	-	+++	+++	-	-	-	+	+
Jinato	5	++	+++	++	+	+	-	-	-
Latondu Besar	5	-	+++	+	-	+	+	-	+
Rajuni Kecil	5	+	+++	++	+	++	-	-	-
Tinabo Besar	5	-	+++	++	+	+	-	-	+

Remark:+ = Present, - = Absent (+++, ++, + = dominant -> less domint)
EA (*Enhalus acoroides*), *TH* (*Thalassia hemprichii*), *CR* (*Cymodocea rotundata*), *CS* (*Cymodocea serrulata*), SI (*Siringodium isoetifolium*), *HP* (*Halodule pinifolia*), *HO* (*Halophila ovalis*).

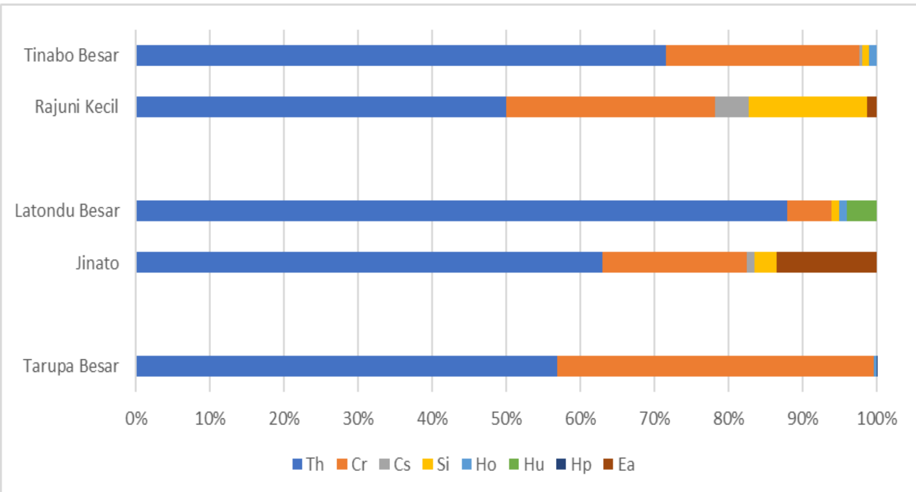

Figure 4. Species cover diversity at five Islands.

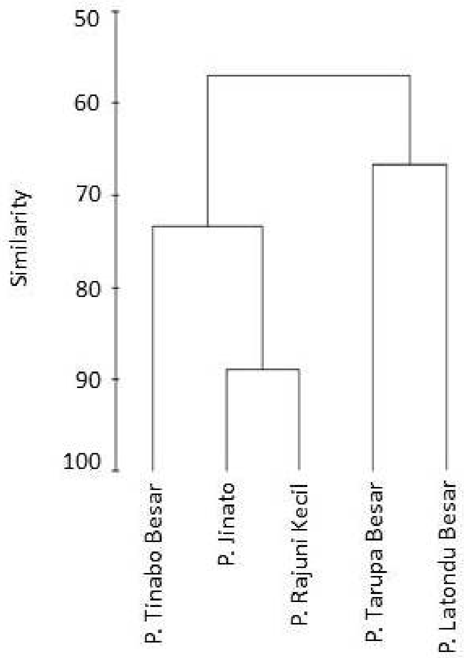

Figure 5. Species cover diversity at five Islands.

Despite changes in species diversity, that is interesting that the species that dominates in the waters of Taka Bonerate National Park since 2003 until now is *Thalassia hemprichii* (*Th*) and then *C. rotundata* (Figure 4). Based on data from Coral Reef Rehabilitation and Management-Coral Triangle Initiative (COREMAP-CTI) 2015-2017 from 386 locations throughout Indonesian waters, 310 locations (85%) of the dominant species were *Thalassia hemprichii* (*Th*) (Sjafrie *et al*., 2018). Seagrass growth is also influenced by the thickness and stability of the substrate which acts as a protector from currents, waves, and nutrient cycles (Kiswara, 2000).

The islands of Jinato, Rajuni Kecil, and Tinabo Besar have similarities in species diversity forming a group with a similarity value of 88.89%. The high similarity value in this group was caused by the diversity and presence of seagrass species found on the three islands together as many as 5 species (Ea, Th, Cr, Cs, and Si) of the 8 total seagrass species found (Th, Ea, Cr, Cs, Si, Ho, Hu, and Hp) and species dominated the growth of *Thalassia hemprichii*. P. Tarupa Besar and Latondu Besar have a similarity of 66.67% and only 3 of the same species were found (Th, Cr, and Ho), but the species is still dominated by *Thalassia hemprichii*. The similarity of seagrass species diversity in the five islands can be grouped into two groups as shown (Figure 5). In general, the similarity value on the five islands observed has a value of >50%, this means seagrasses in the Taka Bonerate Islands have high similarity and diversity of species and are

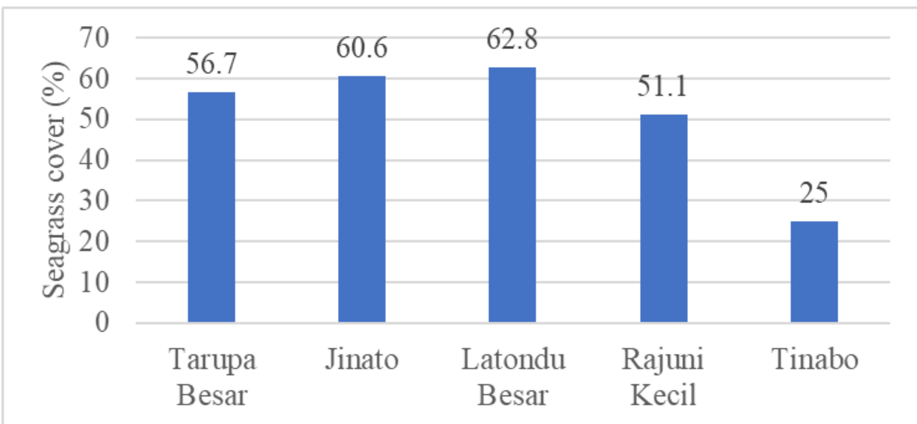

Figure 6. Species cover diversity at five Islands.

Table 5. The results of the fauna identification of megabenthic at some small islands Taka Bonerate National Park

No.	Family/Species	Site* 01	02	03	04	05	06	07	08
Gastropoda:									
	Conidae								
1	*Conus emaciatus*	-	-	+	+	-	+	+	+
2	*Conus litteratus*	-	+	-	+	-	+	+	+
3	*Conus marmoreus*	-	-	-	+	+	+	+	+
	Cypraeidae	-							
4	*Cypraea arabica*	-	+	-	-	-	-	-	-
5	*Cypraea moneta*	+	-	-	-	-	-	-	-
	Nassariidae								
6	*Nassarius albescen*	+	+	+	+	+	-	-	-
7	*Nassarius olivaceus*	-	-	-	-	-	+	-	-
	Strombidae								
8	*Lambis lambis*	-	+	-	+	+	+	-	-
9	*Strombus canarium*	-	+	-	-	-	-	-	-
10	*Strombus gibberulus*	-	+	-	+	-	+	-	-
	Volutidae								
11	*Cymbiola vespertilio*	-	-	-	-	+	+	-	-
Bivalvia:									
	Chamidae								
12	*Chama sp.*	-	-	-	-	-	+	-	-
	Fimbridae								
13	*Fimbria fimbriata*	-	+	-	-	-	-	-	-
	Isognominidae								
14	*Isognomon isognomum*	+	-	+	-	-	-	+	+
	Pinnidae								
15	*Pinna bicolor*	-	-	-	-	-	+	+	+
16	*Pinna muricata*	+	+	-	-	+	+	-	-
	Pteriidae								
17	*Pinctada margaritifera*	-	-	-	-	-	+	-	-
	Tellinidae								
18	*Tellina staurella*	+	+	-	-	-	-	-	-
	Tridacnidae								
19	*Hippopus hippopus*	-	-	-	+	-	-	-	-
Ekinodermata:									
	Asteroidae								
20	*Archaster typicus*	-	+	-	-	-	-	-	-
21	*Protoreaster nodosus*	-	+	-	+	-	+	+	+
22	*Tripneustes sp.*	-	-	+	+	+	+	+	+
	Holohurida								
23	*Holothuria atra*	+	+	-	+	-	+	+	+
24	*Holothuria hilla*	-	-	-	-	-	+	-	-

Remark: + Present – Absent
*Tarupa Besar (st.01 and st.02), Jinato (st.03 and st.04), Latondu Besar (st.05 and st.06), Rajuni Kecil (st.07) and Tinabo Besar (st.08)

evenly distributed on the five islands. The presence of Thalassia hemprichii species which is evenly distributed reflects that the type of substrate on the five islands is generally sandy substrate. This condition is similar to that found on the islands of Ambon and South Lombok in that the species *Thallasia hemprichii* is dominant on sandy substrates (Tupan & Uneputty, 2018; Azkab & Kiswara, 1994).

Seagrass Cover

Tarupa Besar and Rajuni Kecil islands have seagrass areas of 248.9 ha and 146.1 ha, respectively. These islands have seagrass cover percentages of 56.7 and 51.1 so they can be categorized as “dense” with 51-75% seagrass cover (Rahmawati *et al*, 2017). The highest percentage of seagrass cover 62.8% was only at the island of Latundu Besar with an area of 721.5 ha, while the percentage cover of 60.6% with an area of 225 ha was found at the Jinato island. Both islands are categorized as “dense” seagrass cover. Tinabo Besar Island is one of the islands that has a relatively narrow area of 63.33 ha and the percentage of cover is only 25% so it is categorized as a “rare” seagrass cover range between 0-25%. Overall, the five small islands in Taka Bonerate National Park have an average seagrass cover percentage of 51.34 and are categorized as “solid”. The following is the distribution of the percentage of seagrass cover across five islands (Figure 6).

Megabenthic Composition

A total of 24 species of megabenthos had identified from 24 transects on the islands of Tarupa Besar, Jinato, Latondu Besar, Rajuni Kecil, and Tinabo Besar, consisting of 11 species (6 genera) gastropod, 8 species (7 genera) bivalves, and 5 species (4 genera) echinoderm (Table 5).

Gastropod from the genus Conidae and Strombidae, have a greater number of species compared to other genera, and also found at least 4 study sites. From this study, all megabenthos fauna are common species and can easily be found in Indonesian waters. From a total of 212 individuals of the fauna of megabenthos collected, highest percentage was gastropods with 42.43% (90 individuals), followed by echinoderms with 39.15% (83 individuals), and lowest was bivalves with 18.40% (39 individuals).

Seagrass condition in small Island

Based on the weighted scoring for each biotic and non-biotic variable, Latondu Besar Island (316) is in the highest rank followed by Tarupa Besar (204), Jinato (186), Rajuni Kecil (171), and Tinabo Besar islands (131). Seagrass conditions on small islands by considering several other variables (biotic and non-biotic) have provided a result of different assessments. According to the 2004 KMNLH determination, the condition of seagrass in the five small islands in Taka Bonerate National Park are Tarupa Besar (56.7 %), Jinato (60.6 %), Latondu Besar (62.8 %), Rajuni Kecil (51.1 %) and Tinabo Besar (51.1 %) or average of 51.4%, so there are categorized as “unhealthy” (29.9-59.9%). Determining the condition of the seagrass by weighting and considering several biotic and non-biotic variables gives the result that Latondu Besar island is in the highest rank supported by variables such as seagrass extent, percentage of seagrass cover, number of megabenthic species, area of the reef flat and sandy habitat (Table 6).

Latondu Besar Island, with its relatively sparse population (940 people) compare to other islands such as Tarupa Besar (1,384 people), Jinato, and Rajuni Kecil (2,105 people) is assumed to have contributed well to the condition of seagrass on that island. Other things need attention besides the sparse population also the types of activities of the local community. Local community activities in the seagrass bed also contributed to the decline in seagrass conditions such as those occurring in the Spermonde Islands due to livelihood dependence (Nadiarti *et al*., 2012), activities of fishing and transportation boats (Rahayu *et al*., 2019). Besides that, dense population in most of the islands of the archipelago who mostly depend on the subsistence and Small-scale fisheries (Pet-Soede *et al*., 2001), including the fisheries products from seagrass ecosystems, may lead to the high stress of the seagrass condition (Asmus, *et al*., 2006). Furthermore, the daily routine activities of the coastal population in Indonesia, mainly those who live in small islands, are believed may also contribute negative impacts on seagrass meadows and their associated fauna. Several studies have revealed the damage of seagrass beds and negative effects on the associated fauna due to boating

Table 6. The total score of small island seagrass condition based on biotic and non-biotic variables

No.	**Variables**	**Weight %**	**Score TB**	**JT**	**LB**	**RK**	**TB**
	Biotics:						
1	Seagrass extent (ha)	18	36	18	72	18	18
2	Persentage seagrass cover (%)	20	60	60	60	60	20
3	Number of seagrass species (indv)	17	17	24	24	24	24
4	Number of megabenthic species (indv)	15	45	30	60	15	15
5	Macro-algae extent (ha)	8	24	32	8	32	32
	Abiotics:						
6	Sand extent (ha)	8	8	8	36	8	8
9	Reef flat extent (ha)	14	14	14	56	14	14
	Total score	**100**	**204**	**186**	**316**	**171**	**131**

activities, including boat anchoring (Francour *et al*., 1999) and propeller scar (Bell *et al*., 2002; Burfeind & Stunz, 2006). According to (Hemminga & Duarte, 2000), the season's alleged changes can also affect the seagrass development and growth conditions.

CONCLUSION

Latundu Besar Island is one of the small island in the Taka Bonerate National Park which has environmental characteristics, biotic and non-biotic values with "good" seagrass condition or the highest total score compared to other small islands. Assessment of the condition of the seagrass beds by accumulation biotic variables (seagrass extent, seagrass cover, seagrass, and mega benthic species, macroalgae extent, and non-biotic variables (reef flat and sand extent) and a sparse population that may contribute to determining the condition of the seagrass need to be considered. Its complement in determining the condition of the seagrass currently refers only to the percentage of seagrass cover (KMNLH, No. 200 of 2004).

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REFFERENCE

Abbott, R.T., & Dance, P. (1990). Compendium of Seashell. Australia: Crawford House Press. 146-176.

Agustina, L., Zen, L.W. & Zulfikar, A. (2015). The economic value of seagrass ecosystem in Berakit Village, Bintan Regency, Riau Islands Province. *Dinamika Maritim, 5*(1), 52-62.

Anon. (2001). Philippine Coastal Management Guidebook No. 5: Managing Coastal Habitats and Marine Protected Areas. Coastal Resource Management Project of the Department of Environment and Natural Resources. Cebu City. The Philippines. 106 p.

Arifin, T., Bohari, R., & Arlyza I. (2014, in Indonesian). Analysis of space Suitability based on marine agriculture in the small islands around Makassar. *Forum Geografi, 28*(1), 91-102.

Asmus, H., Saleh, A, Litaay, M., & Priosambodo, D. (2006, in Indonesian). Community structure of macrozoobenthos in Barranglompo Island Waters. *Jurnal Biologi 2006*, 0835-4489.

Azkab, M.H., & Kiwara, W. (1994, in Indonesian). Seagrass growth and production in Kuta Bay, South Lombok. In Biological Community Structure of Seagrass beds on the South Coast of Lombok and their Environmental Conditions (Kiswara, W., Moosa, M. K. & Hutomo, M, Eds). Research and Development Center for Oceanology, LIPI. Jakarta: 34-41.

Bell, S.S., Hall M.O, Soffian S. & Madley K. (2002). Assessing the impact of boat propeller scars on fish and shrimp utilizing seagrass beds. *Ecol. Appl. 12*, 206-217.

Burfeind, D.D., & Stunz G.W. (2006). The effects of boat propeller scarring intensity on nekton abundance in subtropical seagrass meadows. *Marine Biology 148*(5), 953-962.

Cardoso, P.G., Pardal, M.A., Lillebø, A.I., Ferreira, S.M., Marques, J.C., & Raffaelli, D., (2004). Dynamic changes of seagrass assemblages under eutrophication and implications for recovery. *Journal of Experimental Marine Biology and Ecology 302*(2), 233–248.

Clark, A.M. & Rowe. F.E.W. (1975). *Monograph of shallow-water Indo-West Pacific echinoderms*, Trustees of British Museum (Natural History), London, i-vii, 1-238, pls. 1 – 31.

Clarke, K.R., & Warwick, R.M. (2001). *Changes in marine communities: an approach to statistical analysis and interpretation*. Plymouth, Natural Environment Research Council. Bourne Press.169 pp.

Coen L.D, & Heck, K.L. Jr. (1991). The interacting effects of siphon nipping and habitat on bivalve (Mercenaria mercenaria (L.) growth in a subtropical seagrass (Halodule wrightii Aschers.) meadow. *J. Exp. Mar. Biol. and Ecol, 145*(1), 1-13.

den Hartog, C. (1970). Seagrass of the World. North-Holland Publishing Company. Amsterdam. London. p 271.

Dharma, B. (2005). Recent and fossil Indonesian shells. Conchbook, HackenGermany. 424p.

Dirhamsyah, (2007). An economic valuation of seagrass ecosystems in East Bintan, Riau Archipelago, Indonesia. *Oseanologi dan Limnologi di Indonesia, 33*(2), 257-270.

English, S., Wilkinson, C., & Baker, V. (1994). Survey Manual for Tropical Marien Resources. ASEAN-Australia Marine Science Project: Living Coastal Resources. Australian Institute of Marine Science, Townsville. 368 pp.

Erftemeijer, P.L., & Lewis III, R.R.R. (2006). Environmental impacts of dredging on seagrasses: a review. *Mar. Poll. Bull, 52*(12), 1553-1572.

Fortes, M.D. (1989). Seagrass: a Resource Unknown in the Asian Region. ICLARM Education Series, Manila, Philippines.

Furkon, N. Nessa, Rappe, R.A. & Cullen-Unsworth L.C. (2020). Social Ecology Drivers and Dynamics of Seagrass Gleaning Fisheries. *Ambio, 49*, 1271-1281. https://doi.org/10.1007/s13280-99-01267-x.

Francour, P., Ganteaume, A., & Poulain. M. (1999). Effects of boat anchoring in Posidonia Oceania seagrass beds in the Port-Cros National Park (north-western Mediterranean Sea). *Aquatic Conserv: Mar. Freshw. Ecosyst, 9*(4), 391-400.

Hughes, A.R., & Stachowicz, J.J. (2004). Genetic diversity enhances the resistance of a seagrass ecosystem to disturbance. *Proceedings of the National Academy of Sciences, 101*(24), 8998-9002. https://doi.org/10.1073/pnas.0402642

Green, E.P., Mumby P.J., Edwards, A., & Clark, C. (2000). Remote Sensing Handbook for Tropical Coastal Management. ed Edwards A J. (Paris: The United Nations Educational, Scientific and Cultural Organization).

Green, E.P., & Short, F.T. (2003). *World Atlas of Seagrass. Prepared by the UNEP World Conservation Monitoring Centre*. University of California Press, Berkeley, USA. ISBN 0-520-24047-2. 297p.

Hartoko, A., Kumalasari, I., & Anggoro. S. (2014). To ward a new paradigm of ecosystem and endemic organism based on spatial zonation for Taka Bonerate Marine Protected Area. *International Journal of Marine and Aquatic Resource Conservation and Co-existence, 1*(1), 39-49.

Hedley, J.D., Roelfsema, C.M., Chollett, I., Harborne, A.R., Heron, S.F., Weeks, S., Skirving, W.J., Strong, A.E., Eakin, C.M., Christensen, T.R.L., Ticzon, V., Bejerano, S. & Mumby, P.J., (2016). Remote sensing of coral reefs for monitoring and management: a review. *Remote Sens. 8*(2), 118-157. https://doi.org/10.3390/rs8020118.

Hemminga, M., & Duarte. A.C.M. (2000). Seagrass ecology. Cambridge University Press. Inggris. 298p.

Holmer, M., Argyrou, M., Dalsgaard, T., Danovaro, R., Diaz-Almela, E., Duarte, C. M., et al. (2008). Effects of fish farm waste on Posidonia oceanica meadows: synthesis and provision of monitoring and management tools. *Mar. Poll. Bull, 56*(9), 1618-1629. DOI: 10.1016/j.marpolbul.2008.05.020.

Papenbrock, J. (2012). Highlights in Seagrasses' Phylogeny, Physiology, and Metabolism: What Makes Them Special?. *International Scholarly Research Notices, 2012*. doi:10.5402/2012/103892

Takabonerate Distric in Figures. (2019, in Indonesia), Statistics Agency of Selayar Islands Regency.

Keputusan Menteri Negara Lingkungan Hidup. (2004, in Indonesian). Decree of the State Minister of Environment Number 200 of 2004 regarding Standard Criteria for Damage and Guidelines for Determining the Status of Seagrass Beds,16 p.

Kuo, J. (2007). New monoecious seagrass of Halophila sulawesii (Hydrocharitaceae) from Indonesia. *Aquatic Botany, 87*(2), 171-175.

Kuriandewa, T.E., Kiswara, W., Hutomo, M., & Soemardihardjo, S. (2003). The seagrass of Indonesia. In. World Atlas of Seagrass. (Ed. Green E.P. & Frederick T. Short). University of California Press. pp.171 - 182.

Kiswara, W. (2000, In Indonesian). Community structure of seagrass beds in Indonesian waters. In: Inventory and evaluation of marine-coastal potential, geology, chemistry, biology, and ecology. Indonesian Institute of Sciences. Jakarta, 54-61.

McKenzie, L.J., & Campbell, S.J. (2002). Manual for Community (citizen) Monitoring of Seagrass Habitat-Western Pacific editions, Queensland Fisheries Service, NFC, Cairns, 43, Pp.

McKenzie, L.J., Campbell, S.J., & Order, C.A. (2003). Seagrass-Watch: Manual for Mapping and Monitoring Seagrass Resources by Community (citizen) volunteer. 2nd Edition (QFS, NFC, Cairns) 100 pp.

McKenzie, L.J. (2007). Relationships between seagrass communities and sediment properties along the Queensland coast. Progress report to the Marine and Tropical Sciences Research Facility. Reef and Rainforest Research Centre Ltd, Cairns (25pp).

Nadiarti., Riani, E., Djuwita, I., Budiharsono,S., Purbayanto, A., & Asmus. H. (2012). Challenging for seagrass management in Indonesia. *Journal of Coastal Development, 15*(3), 234-242.

Nienhuis, P.H., & Kiswara, W. (1989). Community structure and biomass distribution of seagrasses and macrofauna in the Flores Sea, Indonesia. *Netherlands Journal of Sea Research, 23*(2), 197-214.

Nellemann C., E. Corcoran, C.M. Duarte, L. Valdés, C. De Young, L. Fonseca, & G. Grimsditc (Eds). (2009). Blue Carbon. A Rapid Response Assessment. UNEP. GRID-Arendal. www.grida.no.

Orth, R.J., Carruthers, T.J.B. Dennison, W.C. Duarte, C.M.. Fourqurean J.W, Heck K.L. Jr., Hughes A.R., Kendrick G.A., Kenworthy W.J., Olyarnik, S. Short, M. Waycott. F. T, &. Williams. S.L (2016). A Global Crisis for Seagrass Ecosystems. *BioScience, 56*(12), 987-996.

Pet-Soede, C., van Dense W.L.T, Pet, J.R, &. Machiels M.A.M (2001). Impact of Indonesian coral reef fisheries on fish community structure and the resultant catch composition. *Fisheries Research, 51*(1), 35-51.

Poutiers, J. (1998). *The living marine resources of the Western Central Pacific.Vol. 1: Seaweeds, corals, bivalves, and gastropods*. FAO of the United Nation. 686p.

Phinn, S., Roelfsema, C., Dekker, A., Brando, V., & Anstee, J. (2008). Mapping seagrass species, cover and biomass in shallow waters: An assessment of satellite multi-spectral and airborne hyper-spectral imaging systems in Moreton Bay, Australia. *Remote Sensing of Environment, 112*(8), 3413-3425.

Rahayu, Y.P., Solihuddin, T., Kusumaningtyas, M.A., Ati, R.N.A., Salim, H.L., Rixen, T. & Hutahaean, A.A. (2019). The Sources of Organic Matter in Seagrass Sediments and Their Contribution to Carbon Stocks in the Spermonde Islands, Indonesia. *Aquatic Geochemistry, 25*, 161-178. .

Rahmawati, S., Irawan, A., Supriyadi, I.H., & Azab, M.H. (2017, in Indonesian). *Guide for Monitoring Seagrass Bed, Coremap-CTI*. Research Center for Oceanography, Indonesian Institute of Sciences, Jakarta: 50 pp.

Short, T., & Coles, R.G. (eds) (2001). Global Seagrass Research Methods. Elsivier Science B.V., Amsterdam. ISBN 0-444-50891-0. 468 p.

Short, F.T., McKenzie, L.J., Coles, R.G., & Gaeckle, J.L. (2004). *SeagrassNet Manual for Scientific Monitoring of Seagrass Habitat-Worldwide* edition. University of New Hampshire, USA; QDPI, Northern Fisheries Centre, Australia. 71 pp.

Sjafrie, N.D.M., Hernawan, U.E., Prayudha, B., Supriyadi, I.H., Iswari, M.Y., Rahmat., Anggraini, K., Rahmawati, S., & Suyarso. (2018, in Indonesian). *Status of Indonesian Seagrass Meadows 2018*. Research Center for Oceanography-Indonesian Institute of Sciences: 40 pp.

Sjafrie, N.D.M., Rahmadi, P., Kurniawan, F., & Supriyadi, I.H. (2021). Socio-Ecology System Perspective of Seagrass Ecosystem in Wakatobi. International Symposium on Aquatic Science and Resources Management. *IOP Conf.Series: Earth and Environmental Science, 744*(2021), 012078. DOI: 10.1088/1755-1315/744/1/012078.

Thomlinson, P.B. (1974). Vegetative morphology and meristem dependence: The Foundation of Productivity in seagrass. *Aquaculture, 4*(2), 107-130.

Tupan, C.I., & Uneputty, P. (2018). Growth and Production of Leaves Thalassia hemprichii on The Suli Coastal Waters, Ambon Island. *International Journal of Marine Engineering Innovation and Research, 2*(2), 112-116.

Vermaat, J.E., Agawin, S.R.N., Duarte, C.M., Fortes, M.D., Marba, N., & Uri, J.S. (1995). Meadow maintenance, growth, and productivity of a mixed Philippine seagrass bed. *Marine Ecology Progress Series, 124*(1-3), 215-225. DOI:10.3354/meps124215.

Vinh, M.K., Shrestha, R., & Berg, H. (2008). GIS-Aided marine conservation planning and management: A case study in Phuquoc Island, Vietnam. *Paper presented at the International Symposium on Geoinformatics for Spatial Infrastructure Development in Earth and Aplied Sciences 2008*.18 pp.

Waycott, M., Duarte, C.M., Carruthers, T.J.B., Orth, R.J., Dennison, W.C., Olyarnike, S., Calladine, A., and Fourqurean, J.W. (2009). Accelerating loss of seagrasses across the globe threatens coastal ecosystems. *Proceedings of the National Academy of Sciences of the United States of America (PNAS), 106*(30), 12377-12381. www.pnas.org/cgi/doi/10.1073/pnas.09055620106.

Wood, E.J.F., Odum, W.E., & Zieman, J.C. (1969). *Influence of seagrass on the productivity of coastal lagoons*. In: Memoirs Symposium International Costeras (UNAM-UNESCO). Nov. 28-30, 1967, 495-502.