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Species Distribution and Coverage of Seagrass in the Moramo Bay Marine Protected Area (MB-MPA), Southeast Sulawesi Province, Indonesia

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ABSTRACT

The Indonesian government has established Marine Protected Areas (MPAs) to safeguard marine resources and associated ecosystems, including seagrass, coral reefs, and mangroves. Moramo Bay, covering 21,902.34 ha, was designated as an MPA through the Decree of the Minister of Maritime Affairs and Fisheries of the Republic of Indonesia Number 22 of 2021. Within this bay, seagrass, coral reef, and mangrove ecosystems are interconnected and interact physically, chemically, and biologically. This study aimed to assess the species distribution and condition of seagrass coverage in the Moramo Bay Marine Protected Area (MB-MPA). Nine observation stations were established, representing a total seagrass ecosystem area of 1,168.47 ha. The sample plot method was applied to evaluate seagrass bed conditions. Six seagrass species were identified, with *Enhalus acoroides*, *Cymodocea rotundata*, and *Thalassia hemprichii* dominating. Seagrass coverage across stations ranged from 25.00 to 91.67%, with an average of 54.44%, classified as less healthy. Consequently, 45.56% of the seagrass was categorized as moderately damaged. The ecological quality of the seagrass beds, analyzed using the seagrass ecological quality index (SEQI), yielded an index value of 0.67, indicating a moderate category. These findings may serve as a reference for local government in developing strategies for the sustainable management of seagrass ecosystems within the MB-MPA.

INTRODUCTION

Indonesia has a coastline of approximately 108km with a sea area of 6.4 million km² **(Fahrurozi, 2022)**. Millions of people living in coastal areas depend on marine resources for their livelihoods and daily activities. To protect and preserve these resources from pollution, damage, and over-exploitation, the Indonesian government

develops Marine Protected Areas (MPAs). These areas ensure that resources can be sustainably utilized by the population. An MPA is a designated coastal and marine area that serves as a refuge for marine biota to spawn and reproduce, supporting high biodiversity such as healthy seagrass, coral reef, and mangrove ecosystems, while also safeguarding fish resources. Such protected areas contribute to sustainable fisheries and tourism activities, while restoring coastal and marine habitats that are otherwise at risk of degradation.

Moramo Bay is one of Indonesia's MPAs, covering 21,902.34 hectares. It is located in Southeast Sulawesi Province, South Konawe Regency, and encompasses three sub-districts: Moramo, North Moramo, and Laonti. This bay was designated as an MPA through the Decree of the Minister of Maritime Affairs and Fisheries of the Republic of Indonesia Number 22 of 2021, under the aquatic park category. This classification is based on Ministerial Regulation Number 31 of 2020 concerning protected area management, which divides protected areas into three categories: aquatic parks, sanctuaries, and maritime conservation areas. Moramo Bay is qualified as an aquatic park because it meets several criteria:

1. It has extensive waters that support ecological processes.
2. It has the potential to become a natural world heritage site.
3. It possesses aquatic biodiversity, natural uniqueness, and high potential for aquatic ecotourism, sustainable fisheries, traditional fishing, and environmentally friendly aquaculture.
4. It contains representative coastal ecosystems such as seagrass, coral reefs, and mangroves that remain pristine and natural.

The interconnectedness and interaction between seagrass, coral reefs, and mangrove ecosystems support the sustainability and diversity of marine biota **(Barbier *et al.*, 2011; Anggoro *et al.*, 2019)**. Ecologically, seagrass ecosystems function as primary producers, habitats for marine biota, sediment stabilizers, nutrient recyclers, and carbon sinks in the ocean **(Gillis *et al.*, 2014; Potouroglou *et al.*, 2017; Huxham *et al.*, 2018; Lin *et al.*, 2018)**. However, as industrial activity and development in coastal areas increase, ecological pressure on seagrass ecosystems also intensifies, leading to degradation and loss of their ecological roles.

Seagrass generally grows in shallow, sandy waters and is often found in coral reef areas. These plants are monocots (one-seed plants) from the Angiospermae class, with rhizome roots, leaves, and fruits adapted to life underwater. Seagrass ecosystems are distributed across subtropical and tropical regions, but the Indo-Pacific region has the greatest seagrass diversity compared to other regions **(Short *et al.*, 2007)**. Of the 60 species recorded worldwide, 13 species of seagrass are found in Indonesia, belonging to two families (Hydrocharitaceae and Potamogetonaceae) and comprising seven genera **(Fortes *et al.*, 2018; Hidayah *et al.*, 2019)**.

Since the designation of Moramo Bay as an MPA, little has been published about the condition of seagrass in the area. Therefore, this study aimed to assess the current species distribution and seagrass cover within the Moramo Bay MPA (MB-MPA). Such information is urgently needed to support ecosystem-based management and to maintain the balance of the marine environment.

MATERIALS AND METHODS

Study area

Data collection in the MB-MPA was carried out in August-November 2024 at 9 (nine) stations using the transect plot method. Observation stations were determined based on the presence and representation of seagrass ecosystems in the MB-MPA.

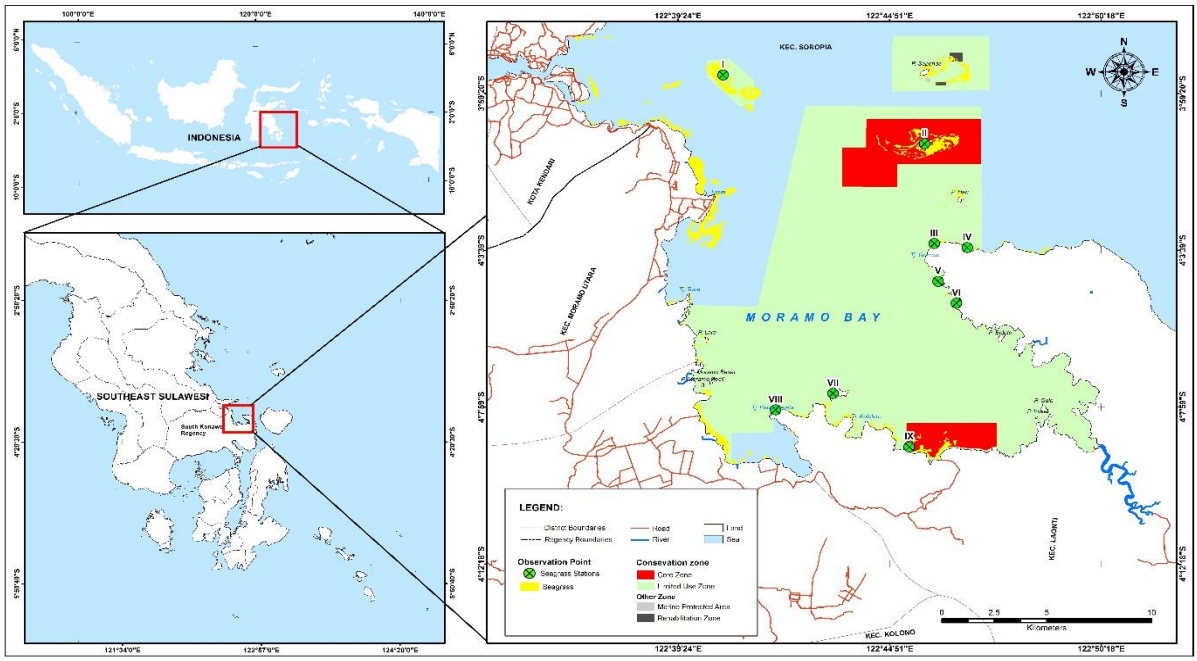

Fig. 1. Nine observation stations for seagrass in MB-MPA indicated by green dots and Roman numbering

Table 1. Observation stations for seagrass in MB-MPA

Station	Location	Geographic coordinates	
		E	S
I	Pasi Jambe	122º40'33.639"	3º58'49.500"
II	Pulau Hari	122º45'45.120"	4º0'43.240"
III	Tanjung Gomo	122º46'0.010"	4º3'28.260"
IV	Pasir Panjang	122º46'51.040"	4º3'35.110"
V	Labotaone	122º46'5.940"	4º4'31.040"
VI	Tanjung Lemo	122º46'34.380"	4º5'7.030"

VII	Rumbi-Rumbia	122º43'23.530"	4º7'35.920"
VIII	Wawosunggu	122º41'54.830"	4º8'3.190"
IX	Panambea Barata	122º45'21.217"	4º9'4.490"

Sampling

The seagrass species present along each transect line were observed and recorded following previous studies **(Den Hartog, 1970; Tomascik *et al.*, 1997; McKenzie & Yoshida, 2009)**. The transect and sample plot method was employed to assess the condition of seagrass beds. This method involves sampling population units from a community using plots established along a line drawn through the seagrass ecosystem area. Seagrass distribution and coverage were determined using the quadrat transect method **(English *et al.*, 1997; McKenzie & Yoshida, 2009)**.

Seagrass coverage was observed using the following procedure:

1. Along each transect line, sampling points were established at intervals of 10– 20m.

2. At each sampling point, a 50 × 50 cm² plot was placed to determine seagrass coverage. This plot was further divided into 25 subplots measuring 10 × 10cm each (Fig. 2). The percentage of seagrass coverage was estimated using the method developed by Saito and Atobe **(English *et al.*, 1997)**.

3. Sampling was conducted in triplicate, and the average of three replications was used to represent seagrass coverage at each point.

Finally, the number of individuals of each seagrass species within each plot was recorded and categorized into appearance classes based on Table (2).

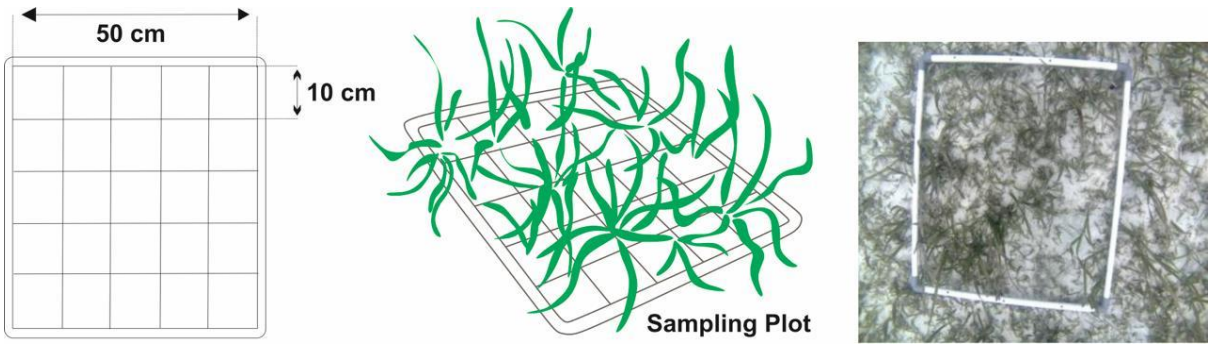

Fig. 2. Sample plot method (after Decree of the Minister of Environment of the Republic of Indonesia Number 200 of 2004) for collecting seagrass data in MB-MPA

Table 2. Seagrass coverage area based on species appearance class

Class*	Size of the coverage area	Coverage area percentage (%)	Midpoint percentage (%)
5	½ - full	50 - 100	75
4	¼ - ½	25 - 50	37.5
3	⅛- ¼	12.5 - 25	18.75
2	$^1/_{16}$ - ⅛	6.25 – 12.5	9.38
1	< $^1/_{16}$	<6.25	3.13
0	None	0	0

* Based on the Decree of the Minister of Environment of the Republic of Indonesia Number 200 of 2004

Data analysis

The coverage of seagrass species in each plot was calculated using a formula: $C=\Sigma(Mi \times fi)/\Sigma fi$, where C is the coverage percentage of seagrass species *i*; M*i* is the midpoint percentage of the appearance class of seagrass species *i*; and f*i* is the number of subplots with the similar appearance class of seagrass species *i* **(English *et al*., 1997)**.

The level of damage to seagrass beds greatly governs the condition of the ecosystem. To determine the level of damage, standard criteria are required that spread over all regions in Indonesia. This study used criteria from the Decree of the Minister of Environment of the Republic of Indonesia Number 200 of 2004; standard damage criteria are presented in Table (3) and seagrass status is listed in Table (4).

Table 3. Standard criteria for seagrass damage

Level of damage	Damage area percentage (%)
High	≥ 50
Moderate	30 – 49.9
Low	≤ 29.9

Table 4. Status of seagrass beds

Status	Condition	Coverage percentage (%)
Good	Rich/healthy	≥ 60
	Less healthy	30 – 59.9
Damaged	Poor	≤ 29.9

The ecological condition of seagrass in the MB-MPA was observed using the seagrass ecological quality index (SEQI) **(Hernawan, 2021)**. This index uses 5 (five) main variables in its analysis, those are seagrass species richness, seagrass cover, water brightness, macroalgae coverage, and epiphyte coverage. The greater the value of the number of seagrass species, seagrass coverage, water brightness, macroalgae, and epiphytes found in an area, the better the ecological quality of the seagrass. The formula

is SEQI = $(S_t/S_{ref})*0.2 + (C_t/C_{ref})*0.2 + (W_t/W_{ref})*0.2 + (1-(M_t/M_{max}))*0.2 + (1-(E_t/E_{max}))*0.2$; where S_t is the number of observed seagrass species; S_{ref} is the maximum number of seagrass species; C_t is the coverage percentage of observed seagrass; C_{ref} is the maximum value of seagrass coverage percentage (100%); W_t is the observed water brightness; W_{ref} is the maximum value of water brightness (2m); M_t is the coverage percentage of observed macroalgae; M_{max} is the maximum value of coverage percentage of macroalgae (100%); E_t is the coverage percentage of observed epiphyte; and E_{max} is the maximum value of epiphyte coverage percentage (100%). The SEQI value ranges from 0 to 1 with categories: 0-0.36 = damaged; 0.37-0.52 = poor; 0.53-0.68 = moderate; 0.69-0.84 = good; and 0.85-1 = perfect.

RESULTS

The results of observations at 9 stations in the MB-MPA, with a total seagrass ecosystem area of 1,168.47 ha, found 6 species of seagrass (Table 5).

Table 5. Distribution of seagrass species at 9 observation stations in MB-MPA

Station	*Enhalus acoroides*	*Thalassia hemprichii*	*Cymodocea rotundata*	*Halophila minor*	*Halophila ovalis*	*Syringodium isoetifolium*
I	+	+	+	+		
II	+	+	+		+	
III	+	+	+			+
IV	+	+	+			+
V	+	+	+			
VI	+	+				
VII	+	+	+	+		
VIII	+					
IX	+	+				

The percentage of seagrass cover in the MB-MPA is tabulated in Table (6) and shown in Fig. (4).

Table 6. Percentage of seagrass cover conditions at 9 observation stations in MB-MPA

Station	Seagrass coverage (%)	Condition	Macroalga coverage (%)	Epiphyte coverage (%)	Brightness (m)
I	38.89	Less healthy	0.00	0.00	2
II	58.89	Less healthy	0.00	0.00	0.7
III	91.67	Rich/Healthy	0.00	0.00	1
IV	80.00	Rich/Healthy	0.00	0.00	1
V	61.11	Rich/Healthy	0.00	11.11	0.7
VI	25.00	Poor	0.00	0.00	0.5

VII	50.56	Less healthy	0.00	0.00	0.5
VII I	29.44	Poor	0.00	4.44	1.5
IX	54.44	Less healthy	38.33	4.44	1.5
Ave rage	54.44	Less healthy	4.26	2.22	1.04

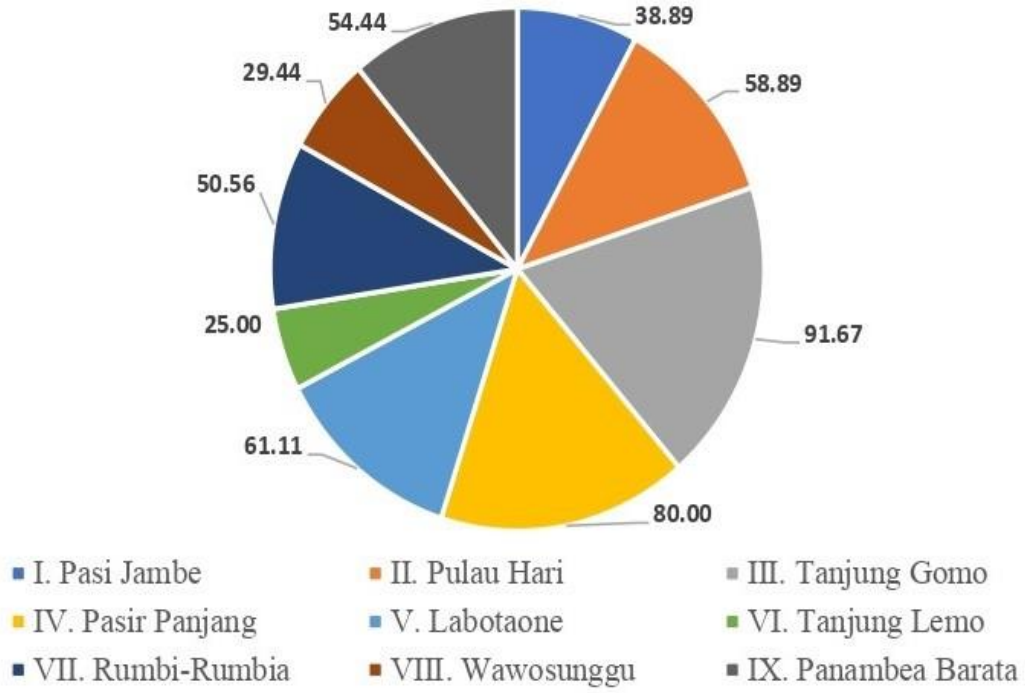

Fig. 4. Percentage of seagrass coverage at the 9 observation stations in MB-MPA

The observation variables such as species richness, seagrass coverage, water brightness, macroalgae coverage, and epiphyte coverage (Table 6) were used in calculating ecological quality using the seagrass ecological quality index (SEQI) (Table 7). The calculation result indicates that the ecological quality of seagrass beds in the MB-MPA is categorized as good, with a SEQI value of 0.67.

Table 7. Results of parameter analysis in SEQI calculations of MB-MPA

Parameter	Analysis Result	N Maxs
Species richness	6	9
Seagrass coverage (%)	54.44	100
Water brightness (m)	1.04	2
Macroalgae coverage (%)	38.33	100
Epiphyte coverage (%)	2.22	100
SEQI	**0.67**	
Category	**Moderate**	

DISCUSSION

Six seagrass species were identified in the Moramo Bay Marine Protected Area (MB-MPA): *Enhalus acoroides*, *Cymodocea rotundata*, *Thalassia hemprichii*, *Halophila minor*, *Halophila ovalis*, and *Syringodium isoetifolium* (Table 5). Compared with previous studies, the number of seagrass species recorded in the MB-MPA is relatively lower than that recorded in several other locations—for example, seven species in the coastal area of Paligue, Hagonoy Davao del Sur, Philippines **(Jumawan *et al.*, 2015)**; seven species in Paklok Bay, Talang District, Phuket Province, southern Thailand **(Koedsin *et al.*, 2016)**; eight species in lagoonal reefs on the Kenyan Coast **(Aboud & Kannah, 2017)**; and 12 species along the Red Sea coast of Saudi Arabia **(Qurban *et al.*, 2018)**. Nevertheless, the presence of six species in the MB-MPA reinforces that Indonesian coastal waters are among the hotspots of seagrass diversity in Southeast Asia **(Fortes *et al.*, 2018)**.

Field observations further showed that the MB-MPA seagrass ecosystem was of the multispecies type, with more than one species occurring within a single bed. Such multispecies assemblages are characteristic of Indo-Pacific seagrass ecosystems, particularly in Indonesia **(Hemminga & Duarte, 2000)**. The distribution of seagrass species in nature is strongly influenced by environmental factors and surrounding water conditions **(Kawaroe *et al.*, 2016)**.

As shown in Table (5), three species—*Enhalus acoroides*, *Thalassia hemprichii*, and *Cymodocea rotundata*—were the most common, with *E. acoroides* found at all nine stations, while *T. hemprichii* and *C. rotundata* were present at eight and six stations, respectively. These species are considered key seagrasses in the Indo-Pacific region **(Short *et al.*, 2007)**. Both *E. acoroides* and *T. hemprichii* are dominant species widely distributed across Indonesian waters **(Hernawan *et al.*, 2021)**. They are categorized as persistent species because of their high adaptability to various aquatic environmental conditions **(Kilminster *et al.*, 2015)**.

Thalassia hemprichii in particular is a cosmopolitan species with a broad distribution in Southeast Asian waters **(Waycott *et al.*, 2004)**. Additionally, pioneer species of the genus *Halophila* were recorded at all observation stations. These pioneer species are ecologically important because they can rapidly recover following disturbances in seagrass ecosystems **(Kilminster *et al.*, 2015)**.

Fig. 3. Condition of the seagrass ecosystem in the MB-MPA

Seagrass coverage in the MB-MPA ranged from 25.00 to 91.67%, with an average of 54.44%. Referring to the Decree of the Minister of Environment of the Republic of Indonesia Number 200 of 2004 on Standard Criteria for Damage and Guidelines for Determining the Status of Seagrass Beds, the condition at each station varied considerably. At Station I (Pasi Jambe), with a coverage of 38.89%, the seagrass was classified as unhealthy in the high damage category (61.11%). Station II (Pulau Hari) showed 58.89% coverage, placing it in the less healthy category with moderate damage (41.11%). Station III (Tanjung Gomo) had the highest coverage at 91.67%, which was classified as healthy with a low damage category (8.33%), while Station IV (Pasir Panjang) with 80.00% coverage was also categorized as healthy with low damage (20.00%). Station V (Labotaone) recorded 61.11% coverage and was considered healthy but in the moderate damage category (38.89%). In contrast, Station VI (Tanjung Lemo) had only 25.00% coverage, indicating poor status with a high damage category (75.00%). Station VII (Rumbi-Rumbia) had 50.56% coverage, which was categorized as unhealthy with moderate damage (49.44%), while Station VIII (Wawosunggu) showed 29.44% coverage, placing it in poor condition with high damage (70.56%). Finally, Station IX (Panambea Barata) had 54.44% coverage, which was classified as unhealthy in the moderate damage category (45.56%). Overall, with an average coverage of 54.44%, the seagrass condition in the MB-MPA is generally considered less healthy, corresponding to the moderate damage category (45.56%).

CONCLUSION

Since its designation as a Marine Protected Area (MPA) by the Government of the Republic of Indonesia, the condition of seagrass in Moramo Bay has received limited attention. In this study, a total of six seagrass species were identified, namely *Enhalus acoroides*, *Thalassia hemprichii*, *Cymodocea rotundata*, *Halophila minor*, *Halophila ovalis*, and *Syringodium isoetifolium*, with the first three species occurring at nearly all observation stations. Although the average seagrass coverage of 54.44% indicates a less healthy status, the ecosystem in the MB-MPA is classified as being in the moderate category, corresponding to a SEQI value of 0.67. The findings of this study provide important baseline data that can guide the planning and management of seagrass ecosystems in the MB-MPA at both local and national levels, thereby supporting the sustainable protection of marine resources, particularly seagrass ecosystems.

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