BIODIVERSITAS
Volume 24, Number 12, December 2023
Pages: 6536-6544

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d241215

Mangrove condition at a marine conservation area at Moramo Bay, Southeast Sulawesi, Indonesia

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Manuscript received: 10 November 2023. Revision accepted: 18 December 2023.

Abstract. *Oetama D, Hakim L, Lelono TD, Musa M. 2023. Mangrove condition at a marine conservation area at Moramo Bay, Southeast Sulawesi, Indonesia. Biodiversitas 24: 6536-6544.* The mangrove ecosystem is one ecosystem that supports biodiversity at the Marine Conservation Area (MCA) in Moramo Bay, Southeast Sulawesi, Indonesia. The area of the mangrove ecosystem in Moramo Bay is approximately 1,933.09 hectares, with an MCA of 1,281.46 hectares. This ecosystem plays an important role in protecting the coastline from erosion due to the seawater filtration process in the bay. This study aims to provide information regarding the status of mangrove ecosystem in the MCA, including species, density, basal area, dominance, and canopy cover percentage, which was used to state the standard criteria for mangrove ecosystem damage. The methods involved a 10×10 m² transect and hemispherical photography using a fisheye lens with a 180° field of view. Seven species of mangrove were found in Moramo Bay MCA, including *Bruguiera gymnorrhiza* (L.) Lam. (dominating with a basal area value of 136,963.66), followed by *Sonneratia alba* Sm. (153,111.90), *Rhizophora mucronata* Lam. (113,708.04), *Rhizophora stylosa* Griffith (28,869.95), *Xylocarpus moluccensis* (Lam.) M.Roem. (9,326.59), *Avicennia marina* (Forssk.) Vierh. (3,419.46), and *Rhizophora apiculata* Blume with a basal area value of 1,690.11. The density of mangrove vegetation was in the criteria of rare to dense, with approximately 800-4,200 individuals per hectare. Furthermore, the mangrove ecosystem in the MCA was found to be damaged up to good condition, with canopy cover percentage values of 45.85%-98.88%. The condition of the mangrove ecosystem in Moramo Bay MCA preserves a basic deliberation for the Indonesian government for adaptive and sustainable management of conservation areas. Protection, preservation, and utilization of mangrove ecosystems should be maximized in all coastal areas to improve the quality of biodiversity.

Keywords: Conservation, mangrove, MCA, Moramo Bay

Abbreviations: MCA: Marine Conservation Area

INTRODUCTION

A conservation area is a geographic area designated, recognized, and managed effectively through government policy (Maini et al. 2023; Reimer et al. 2023). Marine conservation areas play an important role in protecting, increasing, and restoring stocks of fishery resources, which are managed using a zoning system to create sustainable management (McIntosh et al. 2017; Wijayanto et al. 2021). The zoning system consists of a core zone and a utilization zone. The core zone is part of a marine conservation area that aims to protect populations and habitats, while the utilization zone is established for the community's benefit, especially tourism and fishing.

Moramo Bay has been designated as Marine Conservation Area (MCA) based on the Decree of the Minister of Maritime Affairs and Fisheries of the Republic of Indonesia Number 22 of 2021 concerning Conservation Area in the Marine Waters of Moramo Bay in Southeast Sulawesi Province, Indonesia. This location is managed as a water park covering an area of 21,902.34 hectares and consisting of three areas, i.e., area I is a utilization zone with an area of 360.85 hectares, area II consists of a utilization zone of 1,230.79 hectares and other designation zones (rehabilitation and marine protection areas) with an area of 40.61 ha, and area III consists of a core zone and a utilization zone covering areas of 2,242.82 hectares and 18,027.27 hectares, respectively.

Biodiversity in the Moramo Bay marine conservation area is supported by mangrove, seagrass, and coral reef ecosystems, interconnected through physical, biochemical, and biological interactions. Such ecosystems have an important role as habitats for various important fisheries commodities, especially for spawning, nursery, and feeding grounds (Henseler et al. 2019). More broadly, on a global scale, these ecosystems significantly mitigate climate change (Malhi et al. 2020; Hasim 2021; James et al. 2023).

The mangrove ecosystem is closely related to climate change. Mangroves participate in controlling climate change by acting as the world's lungs by absorbing and storing the blue carbon. As a country with the largest mangrove forests in the world, mangrove conservation efforts in Indonesia are the main focus of climate change adaptation programs.

The total mangrove areas in the world are 13.776 million hectares (Giri et al. 2011), of which 25% of the area is located in Indonesia. Mangrove in Indonesia contains a high diversity of flora and fauna (Purwanto et al. 2021; Yudha et al. 2021). The Ministry of Environment and Forestry of the Republic of Indonesia in 2022 has claimed that out of the current 3.48 million hectares of mangrove area, 2.32 million hectares are healthy mangroves with a density of more than 1,500 trees per hectare, while 1.16 million hectares are mangrove ecosystems which are in critical condition with a density of <1,000 trees per hectare. Mangrove damage in Indonesia is generally caused by land conversion into cultivation areas, with the damaging rate reaching 200,000 hectares per year (Ilman et al. 2016; Rahman et al. 2020). Mangroves are considered uniquely adaptable to tolerate a dynamic intertidal environment and full of physiological stress (Srikanth et al. 2016); therefore, their existence deserves protection, including in the Moramo Bay area.

Moramo Bay is a source of livelihood for fishing communities around the bay. Potential fishery resources include capture fisheries (small pelagics, demersal fish, and crustaceans) and aquaculture (Halili et al. 2019). Apart from that, several other important fishery commodities in Moramo Bay, which are the background for the designation of this bay as an MCA, are the presence of lobster seeds, sea turtles, and whale shark passages (Tasidale et al. 2020). Healthy mangroves in coastal areas may increase the resilience of coastal communities to climate change and act as a nursery ground and habitat for economically valuable biota, such as fish, crabs, and shrimp. Since its designation as an MCA, the condition of the mangroves in this area has quite scarcely been published. The study determines the current mangrove ecosystem conditions in the Moramo Bay marine conservation area status. The baseline data of this study may be preserved as a basic consideration by local scale stakeholders for the development of Moramo Bay associated with the conservation of the mangrove ecosystem.

MATERIALS AND METHODS

Study area

Southeast Sulawesi Province is in Indonesia's central region, consisting of 17 districts/cities. Administratively, Moramo Bay MCA is located in three regency/city government administrative areas, i.e., Kendari City, Konawe District, and South Konawe District. Central Bureau of Statistics of Southeast Sulawesi Province quantified that the Moramo MCA has an area of 21,902.34 Ha. South Konawe District contributes the largest area to the total area of MCA, which reaches 20,270.09 Ha, while Konawe District and Kendari City cover 1,271.40 Ha and 360.85 Ha, respectively. The establishment of Moramo Bay MCA began with an initiation from those three regency/city governments, which was strengthened through recommendations from each Regional Head. Figure 1 shows the map of Moramo Bay MCA.

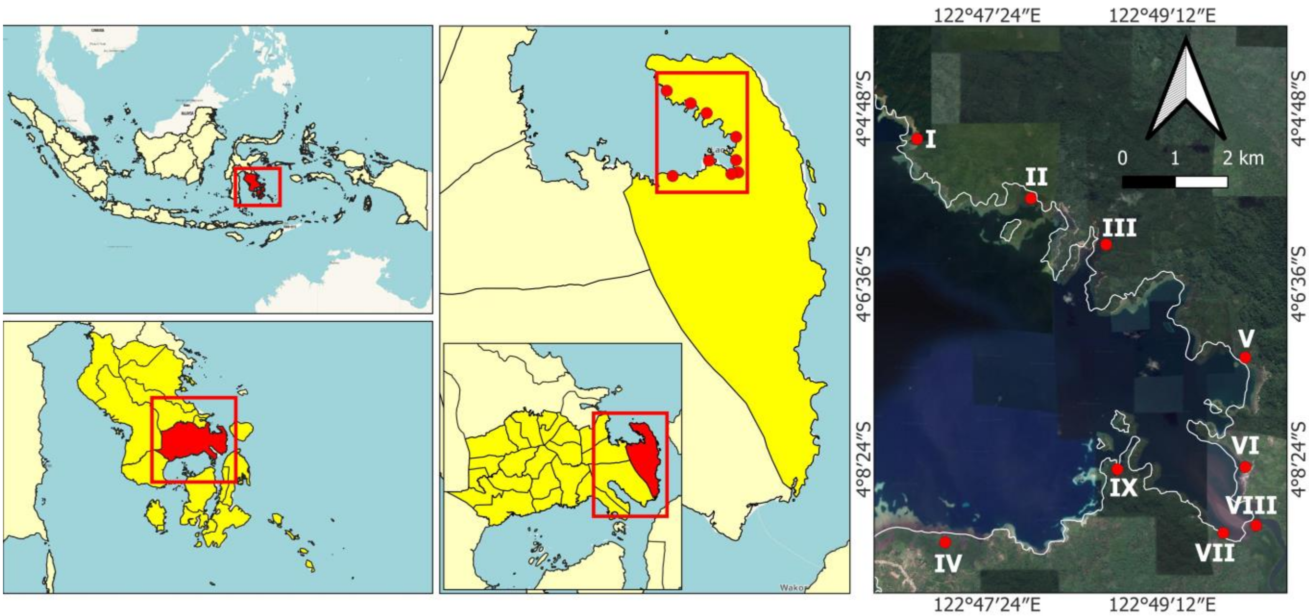

Figure 1. Map of Moramo Bay MCA, Southeast Sulawesi, Indonesia showing nine mangrove observation stations indicated by Roman numerals

Like other areas in Indonesia, Moramo Bay MCA is influenced by dry and rainy seasons. The seasonal conditions are generally influenced by wind currents that blow over each district. From November to March, the wind contains a lot of water vapor originating from the Asian continent and the Pacific Ocean after previously passing through several oceans; the rainy season occurs during these months. Around April, the wind currents are always erratic, sometimes less and sometimes more rainfall; local sailors know this season as the transition. Meanwhile, from May to August, the wind blows from the east, originating from the Australian continent, which contains less water vapor. This results in minimal rainfall in this area in these months; from August to October, there is a dry season.

Sampling

This study was conducted in the Moramo Bay marine conservation area (Figure 1) for 5 months. Mangrove data was collected using purposive sampling at 9 observation stations from 3 June to 28 October 2023. The geographic coordinates of each station are tabulated in Table 1. The collected data includes the number of mangrove species, density, basal area, dominance, and canopy cover percentage.

Data collection on mangrove vegetation was carried out on a 10×10m^2 plot area, initiated with identifying the mangrove species based on references from Tomlinson (2016) and Giesen et al. (2006), then measured all the diameters of mangrove tree trunks (diameter >4 cm or trunk circumference >16 cm) within the plot area (Ahmed et al. 2023). The mangrove canopy cover percentage was quantified using the hemispherical photography method with a fisheye lens with a viewing angle of 180 (at one photo-taking point) (Korhonen et al. 2016; Fournier and Hall 2017).

Table 1. Observation stations in Moramo Bay MCA, Southeast Sulawesi, Indonesia

Station location		Geographic coordinates E	Geographic coordinates S
I	Lemo Cape	122° 46' 40.983" E	4° 5' 06.533" S
II	Labota One Village	122° 47' 51.126" E	4° 5' 43.141" S
III	Tambeanga River	122° 48' 37.510" E	4° 6' 11.562" S
IV	Tambolosu Village	122° 46' 58.302" E	4° 9' 14.952" S
V	Woruworu Village	122° 50' 03.269" E	4° 7' 21.110" S
VI	Wandaeha Village	122° 50' 03.260" E	4° 8' 28.518" S
VII	Laonti Estuary	122° 49' 49.707" E	4° 9' 09.141" S
VIII	River Delta of Laonti	122° 50' 09.922" E	4° 9' 04.483" S
IX	Gala Island	122° 48' 44.456" E	4° 8' 29.956" S

Table 2. Standard criteria for mangrove forest damage

Criteria		Canopy cover (%)	Density (tree/hectare)
Good	Dense	≥75	≥1500
	Medium	≥50 - <75	≥1000 - <1500
Damage	Sparse	<50	<1000

Data analysis

Density (*D*) is the number of individuals per unit area. The density value was calculated using an equation: $D = (\Sigma$ individuals of species i / transect area$) \times 10{,}000$ (Cintron and Novelli 1984). Relative Density (*RD*) is the density percentage of mangrove species in a transect. The relative density value of mangrove trees was calculated using an equation: $RD = (ni / N) \times 100\%$, where n*i* is the number of individuals of the *i*-th species, and N is the total number of individuals of an entire species (English et al. 1997). The evenness index (*E*) was calculated using a formula: $E = H' / \ln S$, where H' is the diversity index and S is the species richness (Krebs 2014). The diversity index (H') was calculated using a formula: $H' = \Sigma[(ni / N).\ln(ni / N)]$, where n*i* is the number of individuals of species *i* and N is the total number of individuals of an entire species (Krebs 2014). The Basal Area (*BA*) of the mangrove was analyzed using a formula: $BA = ¼\ \pi.D^2$, where π is a constant (3.14) and *D* is the tree diameter (cm^2) (Cintron and Novelli 1984). The dominance of mangrove species (*Di*) was calculated using a formula: $Di = \Sigma$ basal area of species i / Σ plot of all sample units (Bengen 2000). The percentage of mangrove canopy cover (%) was analyzed using a formula: % canopy cover = $P255/\Sigma P \times 100\%$, where P255 is the number of pixels with a value of 255 (mangrove canopy cover) and ΣP is the total number of pixels (Dharmawan and Pramudji 2017). The status of mangrove forests can be further determined using the percentage value of mangrove canopy cover, whether sparse, medium, or dense, based on the Decree of the State Minister of Environment, Republic of Indonesia, Number 201 of 2004 concerning Standard Criteria and Guidelines for Determining Mangrove Damage (Table 2). The Importance Value Index (*IVI*) of mangrove species was quantified using an equation: $IVI = RDi + RFi + RCi$, where *RDi* is the relative density of species *i*, *RFi* is the relative frequency of species *i*, and *RCi* is the relative coverage of species *i* (Curtis and McIntosh 1950).

RESULTS AND DISCUSSION

Number of mangrove species

The present study identified 7 species of mangroves spread across 9 observation stations in Moramo Bay MCA, including *Bruguiera gymnorrhiza* (L.) Lam., *Sonneratia alba* Sm., *Rhizophora mucronata* Lam., *Rhizophora stylosa* Griffith, *Xylocarpus moluccensis* (Lam.) M.Roem., *Avicennia marina* (Forssk.) Vierh., and *Rhizophora apiculata* Blume (Table 3). The number of species is lower compared to several coastal areas, for example Air Telang Protected Forest, South Sumatera Province (20 species) (Eddy et al. 2019), Bhitarkanika Wildlife Sanctuary, East Coast of India (19 species) (Rasquinha and Mishra 2021), Gulf of Khambhat, West Coast of India (16 species) (Singh 2020), Konkan Region Mumbai Coast, Maharashtra, India (10 species) (Kantharajan et al. 2018), north-western coast of Sri Lanka (8 species) (Perera et al. 2013), and Rembau estuary, Malaysia (8 species) (Idris et al. 2022). However, the identification of mangrove species on the northern coast of Sri Lanka (Cooray et al. 2019) and Inhambane Bay, Mozambique (Come et al. 2023) archived both 7 species, similar to the number of species found in the study locations. Moreover, 98 mangroves have been archived in Indonesia, consisting of 47 main mangrove species and 51 associated or secondary mangrove species (Nopiana et al. 2020; Rahman et al. 2020). Data from the present study shows that 7 of 47 (3.29%) mangrove species in Indonesia are found in the Moramo Bay MCA, Southeast Sulawesi. The results of this study are in accordance with recent research conducted by Gandri et al. (2023) concerning analysis of changes in mangrove vegetation density for sustainable marine conservation planning management in Moramo Bay. The present study was also carried out in Moramo Bay but spatially has smaller coverage, where our study scope focused on the core and utilization zones of Moramo Bay MCA as indicated by both red and green shaded areas in Figure 1.

Mangrove species found in one location may form monospecies (single) (Martin et al. 2019; Hanggara et al. 2021) or mixed species parallel to the coastline (Santos et al. 1997). Mangrove vegetation typically shows zonation patterns that emerge based on population dynamics, ecophysiology, and geomorphology (Yuvaraj et al. 2017). Differences in the number of mangrove species between one coastal area and another are specifically influenced by tidal inundation, salt tolerance, soil physiochemical properties (Raganas et al. 2020), and other environmental factors, such as the natural condition of the land and its openness to waves (Feng et al. 2020). Mangroves will optimally grow on coastlines that are protected from sea waves with relatively calm coastal currents. Some geographic differentiations are also possibly caused by land constraints or past land constraints due to changing sea levels (Iuit et al. 2020). As a result of rising sea levels, mangrove ecosystems are accustomed to being flooded with seawater, depositing muddy sediments on their roots until they exceed full inundation levels. But as sea levels rise, some ecosystems are flooding faster than they can adapt. Rising sea levels will eventually flood and kill many mangroves on the coast.

Density and relative density

Density in vegetation refers to the number of individuals per unit area. The term consequently refers to the closeness of individual mangroves to one another (Mohd Razali et al. 2020). The density of mangrove tree vegetation in Moramo Bay MCA was 15,500 Ind./Ha. The highest spatial density of mangrove trees was 4,200 Ind./Ha, located at station IV in Tambolosu Village, while the lowest density was at station II in Labota One Village (800 Ind./Ha) (Figure 2). The identification results based on mangrove species showed that the highest mangrove density was *R. mucronata* (7,200 Ind./Ha), with a relative density of 48.64%. The lowest density was found in 2 species of mangrove, *X. moluccensis* and *A. marina*, with density and relative density values of 100 Ind./Ha and 0.68%, respectively (Figure 3).

Density is the number of varieties per unit area, the greater the density, the more individuals per unit area. Density is a unit based on volume, area in a field, and number of stems per hectare, which are acknowledged through relevant measurements (Njana 2020). Furthermore, species density is the number of stands of one species in a unit area, while relative density is the ratio between the number of stands of a species and the total number of stands in a mangrove area (Pototan et al. 2021).

Referring to the Decree of the Minister of Environment of the Republic of Indonesia Number 201 of 2004 concerning Standard Criteria and Guidelines for Determining Mangrove Damage, the total density value of mangrove species at the study location is in the medium criteria, implying that the condition of the mangroves at each station is in fairly good condition. *Rhizophora mucronata* has the highest species density compared to other species in Moramo Bay MCA. Species density may provide clues concerning the abundance of species in a community (McAlpine et al. 2021). The dense growth of mangroves in this location is thought to be governed by river outfalls directly connected to seawater to form estuary areas significantly favored by mangroves to grow. The mixing between freshwater from the Tambeanga and Laonti Rivers and the Moramo Bay seawater influences these water systems' conditions. Mangroves grow optimally in coastal areas with large river estuaries and deltas where the water flow contains mud (Ward et al. 2023).

Table 3. Number of species and distribution of mangroves in Moramo Bay MCA, Southeast Sulawesi, Indonesia

Mangroves species	Station								
	I	II	III	IV	V	VI	VII	VIII	IX
Bruguiera gymnorrhiza (L.) Lam.	-	+	+	+	+	-	-	+	+
Sonneratia alba Sm.	+	-	-	+	-	+	-	-	-
Rhizophora mucronata Lam.	+	+	-	+	+	+	+	+	+
Rhizophora stylosa Griffith	-	-	+	-	+	-	-	-	-
Xylocarpus moluccensis (Lam.) M.Roem.	+	-	-	-	-	-	-	-	-
Avicennia marina (Forssk.) Vierh.	-	+	-	-	-	-	-	-	-
Rhizophora apiculata Blume	-	-	-	-	-	-	-	+	-
Total number	3	3	2	3	3	2	1	3	2

Note: (+): exist, (-): none

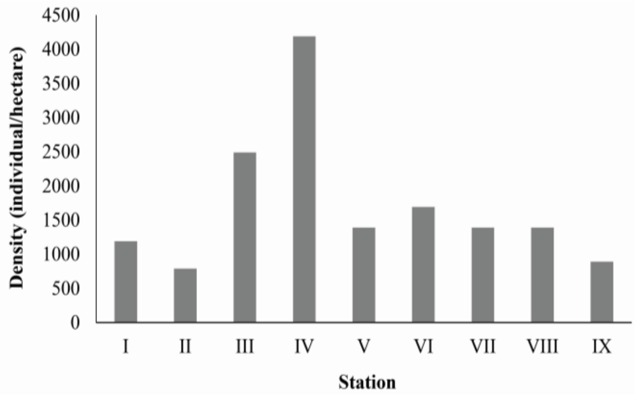

Figure 2. Spatial mangrove density in Moramo Bay MCA, Southeast Sulawesi, Indonesia

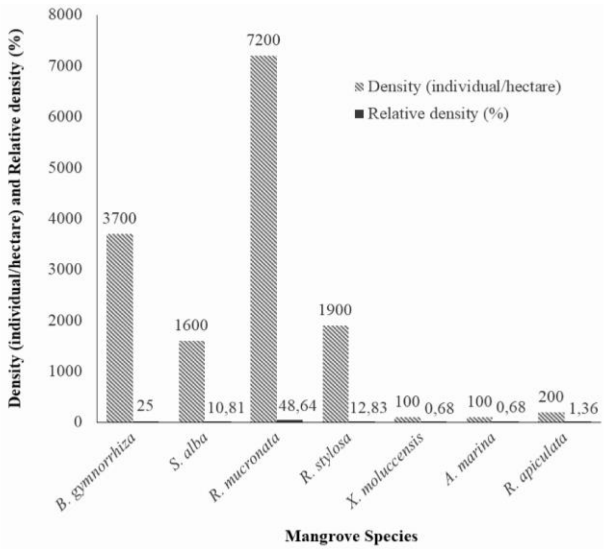

Figure 3. Density and relative density of mangroves in Moramo Bay MCA, Southeast Sulawesi, Indonesia

Mangrove density is important since it closely relates to mangrove forests' ecosystem and ecological function. Decent mangrove density can prevent sunlight from entering the surface of mangrove forests. High mangrove density usually better protects against coastal erosion, tidal wave absorption, and carbon storage (Umroh et al. 2016; Mohd Razali et al. 2020). Apart from that, decent mangrove density (≥1000 Ind./Ha, Table 2) also supports biodiversity by providing habitat for various animal species, such as fish, birds, and invertebrate organisms. Several factors, such as water availability, soil type, and climate conditions, influence the density of mangroves in an area (Friess et al. 2016; Pricillia et al. 2021). Therefore, understanding mangrove density is significantly required for environmental conservation planning and mangrove forest ecosystem management.

Evenness and diversity

The evenness index is used to determine community balance, which is a measure of the similarity in the number of individuals between species in a community. The more similar the number of individuals between species (or the more evenly distributed), the greater the degree of balance. The mangrove evenness index found in this study ranged from 0.0169 to 0.1842 (Table 4), with a total index of 0.6854. Based on Magurran's (1988) criteria, this value refers to the high evenness category, or there are no particular species that dominate one sampling station in the studied area. Our study confirms that *R. mucronata* and *B. gymnorrhiza* have relatively similar numbers of individuals in Moramo Bay MCA. A low evenness index means that the number of individuals of each species is not similar, hence there is a tendency for certain species to dominate. Conversely, if the evenness index is higher, there is no particular species that dominates the community.

A diversity index is a quantitative measure that reflects how many different species exist in a community. High mangrove diversity will be found in communities that consist of many mangrove species and no species dominates. The species diversity index of mangroves found in this study ranged from 0.0329 to 0.3584 (Table 4), with a total index for all species of 1.3337. Such total index shows moderate species diversity (Odum 2004); implying moderate community stability, fairly good productivity, and fairly balanced ecosystem conditions. Roswell et al. (2021) asserted that if a mangrove community consists of a few species and some species dominate, the species diversity will be low. On the other hand, if the mangrove community consists of many species and no species dominates, the species diversity will be high. This study confirms that *R. Mucronata*, *B. gymnorrhiza* and *R. stylosa* are the mangrove species that are often found in Moramo Bay MCA.

Basal area

Basal area is a parameter that measures the cross-sectional area of tree trunks at breast height (1.3 meters high from the ground) in one ecosystem (Oyebade and Anaba 2018). This is an important indicator that reflects the large area occupied by mangrove tree trunks in the ecosystem (Suwa et al. 2021). The highest basal area value in Moramo Bay MCA was found in *B. gymnorrhiza,* with 136,963.66 Ind./Ha, followed by *S. alba* (153,111.90 Ind./Ha) and *R. mucronata* (113,708.04 Ind./Ha) (Table 4). The basal area values for *R. mucronata* and *R. apiculata* obtained in this study were lower compared to those found by Prameswari et al. (2015) and Syarif et al. (2022), with basal area values of 193,4545.55 Ind./Ha for *R. mucronata* in Perancak estuary, Bali Province and 3,799.96 Ind./Ha for *R. apiculata* in Batang Masang Beach, West Sumatra Province, respectively. For *S. alba* species, the basal area value in Moramo Bay MCA was higher than that found in Batang Masang Beach, West Sumatra Province, with 2,472.16 Ind./Ha of basal area (Syarif et al. 2022). The basal area value is relevant to the density of each mangrove species; the higher the basal area value, the better the condition of the mangrove density (Njana 2020).

Basal area measurements are used to analyze and understand the structure of mangrove plants, including tree density, size, and distribution of mangrove trees in Moramo Bay MCA. This information is significant for ecosystem planning and management, including ecosystem restoration and ecological analysis in the studied area.

Table 4. Evenness, diversity, and basal area of mangroves in Moramo Bay MCA, Southeast Sulawesi, Indonesia

Mangroves species	Evenness index	Diversity index	Basal area (Ind./Ha)
B. gymnorrhiza	0.1842	0.3584	136,963.66
S. alba	0.0793	0.1543	153,111.90
R. mucronata	0.1796	0.3495	113,708.04
R. stylosa	0.1170	0.2277	28,869.95
X. moluccensis	0.0793	0.1543	9,336.59
A. marina	0.0169	0.0329	3,419.46
R. apiculata	0.0291	0.0567	1,690.11

Table 5. Mangrove canopy cover percentage in Moramo Bay MCA, Southeast Sulawesi, Indonesia

Station	Canopy coverage (%)	Criteria
I	70.82	Moderate
II	45.85	Rare
III	90.77	Dense
IV	98.88	Dense
V	73.94	Moderate
VI	84.85	Dense
VII	73.94	Moderate
VIII	73.94	Moderate
IX	48.33	Rare

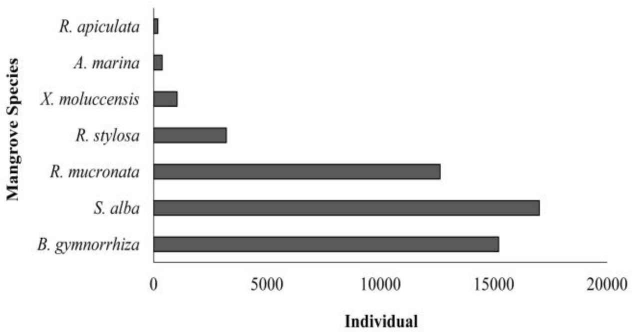

Figure 4. Dominance of mangrove species in Moramo Bay MCA, Southeast Sulawesi, Indonesia

Dominance

Mangrove dominance refers to the condition where one or several mangrove species are significantly more abundant or dominant than those of other species in an ecosystem or a particular part of the ecosystem (Raganas et al. 2020). This describes the proportion of trees from one or several particular species compared to other species in terms of the number or cross-sectional area of tree trunks. The dominance of mangrove species from the highest to the lowest in the study area were *Bruguiera gymnorrhiza* (15,218.18 individual), *Sonneratia alba* (17,012.43 individual), *Rhizophora mucronata* (12,634.23 individual), *Rhizophora stylosa* (3,207.77 individual), *Xylocarpus moluccensis* (1,036.29 individual), *Avicennia marina* (379.94 individual), and *Rhizophora apiculata* with a dominance value of 187.79 individual (Figure 4).

The dominance value determines how much a biota group dominates another group. The high density of *B. gymnorrhiza* mangrove species found in Moramo Bay MCA is probably due to the ability of this species to adapt to its growing environment (Saiyood et al. 2013; Syarif et al. 2022). Ecologically, *B. gymnorrhiza* is the highest dominant species in mangrove forests and is characteristic of the final stages of the development of coastal forests and the early stages in the transition to terrestrial vegetation types. This mangrove species is tolerant of protected areas and those that receive direct sunlight and grow on land edges, as well as tidal and brackish areas (Kusmana et al. 2018). Mangrove dominance may vary from one mangrove ecosystem to another, and dominance changes may reflect the ecology and environmental conditions in the ecosystem. Studies related to mangrove dominance are required to understand mangrove forest ecology; different mangrove species may provide different ecological roles in an ecosystem, and changes in dominance may have a major impact on the structure and function of mangrove ecosystems.

Canopy cover percentage

The canopy cover percentage is a measurement that refers to the proportion of the ground surface area covered by plant canopy (such as trees, bushes, or other plants) in a certain area (Paletto and Tosi 2009). This reflects the extent to which the area is covered by leaves or plant branches that form the roof of the forest or growing vegetation (Sraun et al. 2022). The mangrove canopy cover percentage in Moramo Bay MCA ranged from 48.33-98.88%. The percentage with rare criteria was found at stations II and IX, moderate at stations I, V, VII, and VIII, and dense canopy cover at stations III, IV, and VI (Table 5). Such percentage of canopy cover in this study is slightly lower than the mangrove ecosystem in the Cananeia-Iguape lagoon estuarine system, southeastern Brazil (70%), which is dominated by moderate criteria (Rovai et al. 2021a, 2021b, 2022).

The canopy cover percentage may provide information concerning vegetation structure and coverage in the mangrove ecosystem in Moramo Bay MCA, which is essential in managing the bay ecosystem in the future associated with environmental change, ecosystem restoration, and land management. For example, tree diameter, which is one of the stand parameters on mangrove vegetation structure, was found to influence the canopy cover percentage of mangroves along the Bintuni riverbank areas, West Papua, Indonesia. Increasing the diameter of mangrove trees will increase the percentage of canopy cover in the Bintuni River area (Sraun et al. 2022). Furthermore, Pamungkas et al. (2023) emphasized that the canopy cover percentage of *R. mucronata* and *A. marina* studied in Genuk District, Central Java, Indonesia affected the mangrove vegetation cover and ultimately influenced the intensity of incoming light reaching the mangrove ecosystem.

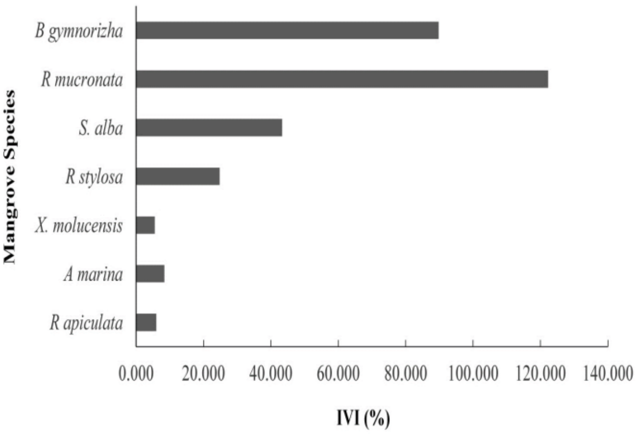

Figure 5. Importance Value Index (IVI) of mangrove species in Moramo Bay MCA, Southeast Sulawesi, Indonesia

Importance Value Index (IVI)

The Importance Value Index (IVI) of mangrove vegetation is a measure of how important the role of certain species of mangroves in forming mangrove ecosystem. IVI of mangrove has a value between 0 and 300. The present study showed that *R. mucronata* found in Moramo Bay MCA has the highest average IVI of 122.276%, followed by *B. gymnorhiza* (89.782%), *S. alba* (43.136%), *R. stylosa* (24.769%), *A. marina* (8.372%), *R. apiculata* (5.971%), and the lowest one was *X. molucensis* with an IVI of 5.514% (Figure 5). Those results indicate that *R. mucronata* plays a dominant role in the mangrove ecosystem of the studied area since this species can grow well on muddy substrates which was found at all observation stations. Raymond et al. (2010) emphasized that mangrove species with high IVI have a greater cumulative control value in their habitat.

In conclusion, the density, relative density, basal area, dominance, and canopy cover percentage have been calculated at the nine stations at Moramo Bay MCA. The current condition of mangroves in the studied area is practically good, with *Bruguiera gymnorrhiza* as the dominant species. A rehabilitation program as an imperative step to improve the environment and enrich mangrove species, requires involvement from the entire community and related stakeholders. The mangrove ecosystem in Moramo Bay MCA may ultimately absorb and store blue carbon to reduce the impact of climate change, both locally and regionally.

ACKNOWLEDGEMENTS

A Grant-in-Aid from Universitas Halu Oleo, Kendari, Indonesia, partially supported this work. We thank Yustika Intan Permatahati and La Ode Khairum Mastu for their constructive help on the manuscript.

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