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Evaluating mangrove vegetation structure and community participation for integrated conservation management

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ABSTRACT

Background: Mangrove ecosystem in Pulau Seribu is one of the conservation areas in Pulau Seribu National Park. Its existence is very important in maintaining the ecological integrity of Pulau Seribu. Changes in land cover and open space area are decreasing, thus affecting global warming, supporting sea level rise, and damaging mangrove ecosystems. This research is to analyze the condition of mangrove ecosystems, socio-economic conditions of the community, and efforts to optimize mangrove ecosystem conservation areas on Pramuka Island. **Methods**: The method used for primary data was the line plot method and measurement of supporting parameters, while secondary data were obtained from literature studies. **Findings:** The results showed that there were three types of mangroves found on Pramuka Island, with seedling and sapling growth levels having the same Importance Value Index of 200. While the pole level obtained the highest *Rhizophora stylosa* (267.74) then *Rhizophora apiculata* (16.39) and the lowest by *Rhizophora mucronata* (15.87). **Conclusion**: Based on the findings of the real conditions on Pramuka Island, it is necessary to repair and improve supporting facilities in the conservation area. The level of community participation on Pramuka Island is very low in mangrove management, with the highest average of 38.15% in the 'Never' answer category. Community-based conservation programs to actively engage in mangrove ecosystem restoration and management. **Novelty/Originality of this article:** Promotion of sustainable alternatives to destructive practices such as mini-tourism, ecotourism, and research/study can help reduce pressure on mangrove ecosystems. Areas covered by mangroves need to be promoted through a zoning system, such as maintenance zone, utilization zone, protection zone, and replantation zone.

KEYWORDS: community; conservation; mangrove ecosystem; pramuka island; zoning

1. Introduction

Indonesia has a geographical structure with a total of 17.508 islands, the coastline surrounding the entire territory of Indonesia reaches 81.000 Km^2, this makes Indonesia a maritime region and 2/3 of its territory is water (Harefa et al., 2020). Water areas form coastal areas that have biological and non-biological potential, one of which is mangroves (Febriana & Utary, 2024; Widayanti et al., 2023). Mangrove ecosystems provide a link between terrestrial and marine ecosystems, characterized by high salinity concentrations, strong wind and tidal forces, muddy sediments and anaerobic soils (Choudhary et al., 2024; Palit et al., 2022; Sarker et al., 2021). Mangrove ecosystems covering 3.3 million hectares are spread across the archipelago, consisting of 2.2 million hectares inside forest areas, and 1.3 million hectares outside forest areas (Nurbaya et al., 2020).

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Indonesia's mangrove ecosystems represent 3.14Pg of carbon stocks that have the potential to contribute to global climate change mitigation, Indonesia's mangrove area occupies nearly 25% of the world's mangrove area (Baderan, 2017). However, the Ministry of Environment and Forestry published a land cover that shows mangrove areas in Indonesia are experiencing a significant decline, from 2,930,352 hectares in 2000 to 2,736,985 hectares in 2020 in Bali and Nusa Tenggara, Java, Kalimantan, Maluku, Papua, Sulawesi, and Sumatra, it is estimated that the decline in mangrove area is 193,367 hectares. Mangrove ecosystems have faced threats over the past few decades largely caused by coastal development activities, such as aquaculture, logging, mining, reclamation, and pollution (Basyuni et al., 2022). The highest mangrove deforestation occurred in 1987-1998, mangrove deforestation can hinder climate change mitigation efforts and reduce mangrove carbon stocks (Chatting et al., 2022).

The total remaining mangroves in the Java Islands are relatively less than those in eastern Indonesia (Basyuni et al., 2022). Continuous and environmentally unfriendly utilization of mangroves will threaten the sustainability of mangrove ecosystems (Akram et al., 2023; Ashton, 2022; Turisno et al., 2021). There is a greater risk of mangrove exploitation in some island groups along the Java Sea, such as the Pulau Seribu. Mangrove species diversity on small islands is relatively lower and vulnerable to climate change due to limited habitat area, higher salinity levels, and massive anthropogenic activities, one of which is on Pramuka Island (Ningsih et al., 2021). Pramuka Island is included in the National Park of Pulau Seribu area of the National Park Management Section III based on the Minister of Forestry Regulation Number: PM.03/MENHUT-II/2007 concerning the Organization and Work Procedures of the National Park Technical Implementation Unit. The development of Pramuka Island has not only led to an increase in economic activity and services, but also the rapid growth of population and tourism (Risqiani et al., 2020).

Pramuka Island is designated as a settlement zone through Decree Number: SK.05/IV-KK/2004 concerning the Management Zoning of the Pulau Seribu National Marine Park. Based on research Barus et al. (2023) The availability of potential land that can be utilized for settlements on Pramuka Island remains 5.01 hectares, the results of the calculation of the threat of extreme waves and abrasion of the coastal area of Pramuka Island amounted to 57.11% of the total length of the coastline. Extreme wave disasters need to be overcome with infrastructure and cultivation activities (Risandi et al., 2021) one of the example is by establishing mangrove ecosystem conservation zoning. Mangrove ecosystems can be a disaster mitigation effort, as a breakwater and prevent abrasion (Syah, 2020). In fact, the use of coastal areas is used as the center of population activities, including in the the National Park of Pulau Seribu area, which for generations still exists in settlement activities and intervenes in the available mangrove ecosystem (Muhammad, 2022; Irman et al., 2021).

According to the Central Bureau of Statistics (2021) Pramuka Island is the fourth most visited island, there are 23,419 tourists from abroad and the archipelago. This development has an impact on the increasing need for clean water, thus affecting land subsidence on Pramuka Island. Changes in land cover and open space area are decreasing, which affects global warming, supports sea level rise, and damages mangrove ecosystems. Sustainable mangrove ecosystems need to be the main focus by optimizing the management zone system. Innovative approaches in the form of strategies to build coastal infrastructure projects, mangrove ecosystems need to be incorporated into the design of protection systems as breakwaters and increase their effectiveness in protecting the coastline. (Damastuti et al., 2022).

Based on the description above, the purpose of this study is to analyze the condition of mangrove ecosystems, socio-economic conditions of the community, and efforts to optimize mangrove ecosystem conservation areas on Pramuka Island. The results of this study are expected to be a source of information for all parties and help in making policies to manage sustainable mangrove forest ecosystems on Pramuka Island.

2. Methods

2.1 Time and place of research

Observations were conducted in February 2022 on Pramuka Island, geographically located at 106°36'50.00” East, 05°44'44.00” LS by the researcher. Government Regulation No. 55/2001 states that Pramuka Island is part of Pulau Panggang Urban Village, North Pulau Seribu District, Pulau Seribu Administrative Regency. The number of people living on Pramuka Island is 1.265 peoples with an area of 10.18 km^2 (BPS Seribu Islands Regency, 2021). Pramuka Island is included in the National Park of Pulau Seribu area of the National Park Management Section III based on the Minister of Forestry Regulation Number: PM.03/MENHUT-II/2007 concerning the Organization and Work Procedures of the National Park Technical Implementation Unit. Based on Decree Number: SK.05/IV-KK/2004 concerning Zoning Management of the Pulau Seribu Marine National Park, Pramuka Island is designated as a settlement zone.

2.2 Mangrove vegetation observation

Mangrove vegetation community structure is known by the Line Transect Method in accordance with the Decree of the Minister of Environment No. 201 of 2004. The Line Transect Method is a method of sampling the population of an ecosystem with a sample plot approach that is on a line drawn through the ecosystem area. The area is determined with a minimum sampling intensity of 10% of the mangrove ecosystem area. The sampling area is made in the form of a 20-meters-long path perpendicular from the beach to the mainland, on each path a measuring plot is made according to the mangrove level. Seedling level of 2m×2m, sapling level of 5m×5m, and pole level of 20m×20m, each measuring plot is made intermittently following the shape of the path. Each measuring plot is done to observe the diameter and number of mangrove stands.

Diameter was measured at a height of 1.3 m perpendicular to the substrate. In mangroves with branching lower than 1.3 m, the diameter was measured on each branch (counted more than one stand). Mangroves with branching higher than 1.3 m, then the diameter is measured at a height of 1.3 m (counted as one stand). Measurement of environmental data (supporting parameters) in each observation block includes salinity, seawater pH, and substrate type. Data obtained from observations and measurements in the field were calculated in the manner conducted by Curtis & McIntosh (1951).

$$Di = Ni/A$$
$$Rdi\ (\%) = \frac{Ni}{\sum ni} \times 100\% \qquad \text{(Eq. 1)}$$

Species density (Di) describes the number of stands of species i within a unit area, where Di refers to the density of species i, Ni represents the total number of stands of that species, and A denotes the total sampling area. Meanwhile, relative density (RDi) refers to the proportion between the number of stands of species i and the total number of stands of all species (∑n). In this context, RDi indicates the relative density of the i-th species, ni represents the total number of stands of that species, and ∑n signifies the total number of stands of all species.

$$F = Pi/\sum P$$
$$RFi = \frac{Fi}{\sum F} \times 100\% \qquad \text{(Eq. 2)}$$

Species frequency (Fi) refers to the likelihood of encountering species i within the observed plot. Relative frequency (RFi) represents the proportion between the frequency of species i and the total frequency of all recorded species (∑F). In this context, RFi denotes the relative frequency of species i, Fi indicates the frequency of the species being observed, and ∑F refers to the total frequency of all species in the study area.

$$Ci = \sum BA/A$$
$$RCi = \frac{Ci}{\sum C} \times 100\% \quad \text{(Eq. 3)}$$

Species cover (Ci) refers to the area occupied by species i within a unit area, where Ci represents the cover area of species i, ΣBA denotes the basal area calculated using the formula $\pi d^2/4$, and A indicates the total sampling area. The relative cover of species (RCi) describes the proportion of the cover area of species i compared to the total cover area of all species (∑C). In this context, RCi refers to the relative cover of the i-th species, Ci indicates the cover area of that species, and ∑C represents the total cover area contributed by all species.

$$IVI = RDi + RFi + RCi$$
$$IVI = RDi + Rfi \quad \text{(Eq. 4)}$$

The importance value index (IVI) is the sum of the relative density of species (RDi), relative frequency of species (RFi), and relative dominance of species (RCi). Seedling and sapling levels in a vegetation using formula (8). This important value is to provide an overview of the influence or role of a mangrove species in the ecosystem. The important value index has a range between 0-300.

2.4 Measurement of physical and chemical factors of mangrove

Measurements of supporting parameters in each observation block include temperature, pH, salinity, and substrate type. Temperature measurements were taken using a thermometer. The thermometer is dipped into the object of measurement in the form of seawater in the mangrove ecosystem, then seen the increase in the line (mercury rise) which shows the amount of water temperature. pH measurements were made using a pH meter. The bottom of the pH meter is dipped into the object of measurement in the form of seawater in the mangrove ecosystem, the amount of pH value is displayed on the screen. Salinity measurements using a Hand Refractometer, water samples are placed on the prime glass and then closed. The results can be seen through the spy glass and show the salinity value. Determination of substrate type was observed visually and texturally as supporting data. The method by massaging and feeling the soil using the fingers to determine the condition of the mangrove ecosystem substrate.

2.5 Secondary data collection

Secondary data was obtained by studying literature related to the research studi through literacy textbooks, journals, and the internet. Secondary data collected in the form of mangrove ecosystem conservation programs include policies and regulations regarding mangrove conservation and evaluation and monitoring of conservation that has been done. Socio-economic conditions of the community include age, education level, occupation, and community participation in mangrove ecosystem management.

3. Results and Discussion

3.1 Mangrove ecosystem condition

Pramuka Island management is included in the settlement zone/utilization zone II in the Pulau Seribu National Park section III on Pramuka Island area for local community use and nature tourism. The existence of mangroves on Pramuka Island greatly affects the living things associated with them. There are three types of mangroves found on Pramuka Island, Rhizophora stylosa is more dominant than Rhizophora apiculata and Rhizopora mucronate. The number of saplings was found more than the number of trees and seedlings (Table 1). Based on the Decree of the Minister of Environment Number 201 of 2004 concerning Standard Criteria and Determination of Mangrove Damage, mangroves with tree categories found on Pramuka Island are included in the medium and very dense categories.

Table 1. Mangrove species

Species	Habitus		
	Seeding	Pole	Stake
Rhizophora stylosa	45	522	86
Rhizophora apiculata	0	0	1
Rhizophora mucronata	0	0	1

Mangrove planting methods can affect mangrove density. The planting method used on Pramuka Island is the spaced clump method, to adjust to the strong tidal current conditions in the coastal area. Evenness in the observation zone has a sand substrate content that supports the growth and density of Rhizophora stylosa species at the pole and sapling levels, so that the density of pole and sapling levels is higher than the tree level of other mangrove species, especially Rhizophora stylosa. Rhizophora stylosa mangroves can live on sand and mud substrates (Lewerissa et al., 2018). Important value shows the importance of a plant species whether or not the plant is influential in the community and ecosystem is shown through the Important Value Index (IVI) which is the sum of relative density, relative frequency, and relative dominance. Based on the INP analysis in Table 2, seedling and sapling growth levels have the same value of 200. While the pole level obtained the highest Rhizophora stylosa (267.74) then Rhizophora apiculata (16.39) and the lowest by Rhizophora mucronata (15.87).

Table 2. Result of mangrove vegetation analysis

Habitus	Species	K	KR (%)	F	FR (%)	Di	DR (%)	IVI
Seeding	*R. stylosa*	0.300	100.00	0.50	100.00	0	0	200.00
Pole	*R. stylosa*	3.413	100.00	0.50	100.00	0	0	200.00
Stake	*R. stylosa*	0.02	97.73	0.67	75.00	0.38	95.02	267.74
	R. apiculate	0.00	1.14	0.11	12.50	0.01	2.75	16.39
	R. mucronata	0.00	1.14	0.11	12.50	0.01	2.23	15.87
Total	-	0.02	100.00	0.89	100.00	0.40	100.00	300.00

The highest relative density at the pole level was shown by the Rhizophora stylosa species at 97.73% which was due to environmental conditions such as pH which was at a normal level, namely pH with a range of 7.5-8.2. The high density of mangrove vegetation indicates that the vegetation community is in an undisturbed condition. The results of the analysis of the frequency value showed that the seedling and sapling levels had the same frequency value of 100% because only the Rhizophora stylosa species were found in the study location. At the tree level, Rhizophora stylosa was found to have a greater relative frequency value (75%) than Rhizophora apiculata and Rhizophora mucronata. This is due to differences in physical and chemical environmental factors in each zone that support the growth of Rhizophora stylosa mangroves. At the pole level, Rhizophora stylosa dominated by 95.02% due to the uniform planting process so that the Rhizophora stylosa species can survive and compete for more nutrients than other species so that the stem volume is large enough and the broad crown that causes the Rhizophora stylosa species the mastery level of a species or dominance is higher than other species. Rhizophora stylosa mangroves in the Pramuka Island area were the first species and area to be planted in 2002.

The dominance of mangrove species varies from species to species in a given area, as larger stem sizes expand their dominance. Species that have relatively low dominance values reflect their inability to tolerate environmental conditions. The influence and role of mangrove species is also influenced by the type of suitable substrate and the ability of mangroves to adapt to their environment. The substrate found in the study site is sand. In habitats that consist of mud with a high sand content, or that have dominant coral fragments, this condition is usually found on the beach adjacent to coral reefs. In addition to the substrate, things that can indicate that mangrove species can regenerate and adapt well to their environment are temperature, pH, and salinity factors in Table 3.

Table 3. Physico-chemical factors of mangrove ecosystem

Factor	East Point	West point
Temperature	21.53^{o}C	29.33^{o}C
pH	7.5	8.2
Salinity	29.73$^{o}/_{oo}$	29$^{o}/_{oo}$
Substrate	Sand	Sand

Environmental parameters at the research site are conditions that support the growth and development of mangroves for photosynthesis and respiration. The condition of mangrove environmental quality and mangrove health on Pramuka Island has a high/good environmental quality and low/bad mangrove health value (Adinegoro et al., 2022). Water quality parameters were reviewed for pollution levels based on seawater quality standards according to the Decree of the Minister of Environment Number 51 of 2004 concerning Seawater Quality Standards for marine biota. Variations in environmental conditions that are submerged in seawater during the highest tides and occur only a few times a month cause naturally formed variations in mangrove vegetation zonation. Mangrove zonation has layers, starting from the outermost part exposed to ocean waves to the area near the shoreline that is relatively dry. Temperature is one of the most important factors for the life of organisms in the ocean, because temperature greatly affects both metabolic activity and development of marine organisms. The water temperature at the research location ranged from 21.53°C and 29.33°C. Based on seawater quality standards for marine biota ranging from 28-32°C, the temperature at the eastern point is less than the normal limit for mangrove ecosystems. The significant difference between the temperature at the eastern and western points is because the level of trees at the eastern point is more so that the observation zone is surrounded by shady vegetation and the sun that enters the water surface becomes less. The degree of pH of the water in the three locations showed relatively normal results (7.5-8.2) because it was still in the range of 7-8.5 in seawater quality standards for marine biota. Seawater has the ability as a buffer in maintaining pH to always be alkaline, so that the value is relatively stable and this system is known as the seawater carbonate system. The high and low pH of water is influenced by the content of compounds in the water.

Salinity in the Pramuka Island mangrove ecosystem ranges from 29.73-29 ppt. Increased salinity can occur due to water evaporation which reduces the volume of water so that the concentration of dissolved salts in it increases. Fluctuations in salinity are influenced by the size of water evaporation, besides the mixing of other water with different salinity and precipitation. The higher the salinity level, the more disturbed plant growth will be. According to the Decree of the Minister of Environment No. 51 of 2004 concerning Seawater Quality Standards, the ideal maximum value for mangrove salinity is 34 ppt. Salinity describes the total concentration of ions contained in a body of water with major constituent ions such as sodium, potassium, magnesium, and chloride. Salinity will vary vertically and horizontally depending on the input of freshwater, rainwater, and evaporation. Salinity plays an important role in the life of marine organisms and the solubility of gases in seawater. Salinity is also one of the environmental factors that influence the presence of mangrove species.

3.2 Mangrove ecosystem conservation

Pramuka Island promotes mangrove conservation under the auspices of the Seribu Islands National Park Center to become one of the tourist destinations in accordance with the Minister of Forestry Regulation Number: PM.03/MENHUT-II/2007. The ecological, economic and social benefits of mangrove ecotourism are interconnected with many other complementary industries. Designated protection sites for mangroves also attract tourists, thus driving the development of a massive tourism industry and all other complementary industries that contribute to the socio-economic development of the country. Based on Law No. 5 of 1990 article 3, all conservation activities must include the preservation of biological natural resources and the balance of their ecosystems, then outlined in the DKI Jakarta RPJMD 2017-2022 as a target in realizing the government's vision and mission. The results of research by Pratiwi et al. (2020) showed that the implementation of the conservation program on Pramuka Island has not been in accordance with its objectives (Table 4).

Table 4. Implementation of the conservation program on Pramuka Island

No	Foundation of the Law	RPJMD DKI Jakarta (2017-2022)	Real Activity	Description
1	Protection of life support system	Construction of signage	Information board on general knowledge of mangroves around the conservation area	No prohibition and direction boards
		Embankment construction	Embankment construction on the west side	Found in part of the National Park
		Mangrove planting and rehabilitation	Mangrove nursery and planting, creation of conservation area	There are two environmental groups (Rumah Hijau and Pesona Karang)
		Environmentally friendly waste management separated from residential areas	Recycling waste into handicrafts, composting	There is still waste burning (9.52 m^3 /day)
2	Biodiversity preservation	Community-based tourism development	Making mangrove tracking tours	Few people take part
		Ecosystem guarding	Monitoring every 2 months	There is no daily guardi
		Development of facilities and infrastructure	Waste bin facilities, temporary waste disposal sites (TPS), toilets and places of worship in conservation areas	TPS is not feasible because it is in the middle of a settlement and near the conservation area
3	Sustainable utilization of natural resources	Construction of floating deck to enjoy mangrove	Construction of floating deck in conservation area	Construction has not been completed
		Development of community-based tourism	Counseling and teaching about mangroves to elementary school students	The target audience is not wide enough

(Pratiwi et al., 2020)

Based on the findings of the real conditions on Pramuka Island, there is a need for improvement and enhancement of supporting facilities in the conservation area. Information boards are very important to provide directions and warnings to conservation visitors. This is supported by the Regulation of the Minister of Tourism Number 3 of 2018 chapter IV concerning Operational Guidelines for the Management of Physical Special Allocation Funds for the Tourism Sector, that information boards are the quality of tourist attractions that are financed. Research Pratiwi et al. (2020) provides information that monitoring and evaluation of conservation areas is only carried out every two months by the manager of the Pulau Seribu National Park on Pramuka Island. Non-structural efforts through direct scale guarding and supervision around the conservation area need to be evaluated regularly, as a criterion for the safety of a location with the presence of area police, beach employees, attention and direction signs. Structural efforts in conservation areas are mangrove planting and embankment construction. Mangrove planting on Pramuka Island is hampered by anthropogenic factors in the form of garbage both carried by currents from the sea, and those generated from land. Pratiwi et al. (2020) also explained that the temporary waste disposal site on Pramuka Island has a location that is prone to pollution.

The level of community participation in mangrove ecosystem management affects conservation on Pramuka Island. Research results by Rizky et al. (2023) shows that the community tends to be passive in rehabilitation activities and planting mangrove seedlings. The study also explained that the level of community participation on Pramuka Island in 2022 was classified as very low in mangrove management, obtained the highest average of 38,15% in the 'Never' answer category which means that respondents are not active in planning, implementing, utilizing, and supervising the scale of the mangrove ecosystem, both in the form of ideas / thoughts, expertise, energy, and funds. Participation in mangrove ecosystem management is influenced by several factors as in Table 5.

Table 5. Factors influencing participation rates

Factor	Description	Percentage
Age	18-29 years	31%
	30-41 years	30%
	42-53 years	26%
	54-65 years	9%
	>65 years	4%
Education Level	Diploma/graduate degree	16%
	Graduated elementary school	12%
	Graduated junior high school	9%
	High school graduate	63%
	Not in school	0%
	Not graduated from school	0%
Job	Government employee	30%
	Trader	22%
	Teacher	6%
	Fisherman	2%
	Carpentry	8%
	Services	21%
	Others	11%

(Rizky et al., 2023)

Research result by Rizky et al. (2023) by distributing questionnaires to respondents on Pramuka Island shows that the age of 31-29 years dominates the population (31%), the increasing age of a person will affect the acceptance of information on new things because physical conditions tend to weaken. The education level of the majority of the community is high school graduates (63%) and the type of work is government employees (30%). The average community in Pramuka Island follows an informal education system organized by the government, thus increasing their ability to develop knowledge related to coastal ecosystems, with the hope that even if they do not continue their education to college, the community can contribute to the management of Pramuka Island. However, the type of work is also a big factor in influencing the time a person has, many people are busy with their work and are less interested in participating in conservation activities regularly. Therefore, the level of community participation in Pramuka Island is low because productive age people tend to be aware of the importance of environmental sustainability, but do not have the time available due to work as a priority.

The type of work and population density on Pramuka Island affect the management of mangrove ecosystems. Mangroves in the Pramuka Island area are managed by the Pramuka Island Regional Management Resort. The Pulau Seribu National Park on Pramuka Island area that includes Pramuka Island is a less than optimal area for mangroves, but the benefits of mangroves have a very positive impact on the environment and living things, so planting and monitoring mangroves is something that needs to be prioritized by all policy makers and the community. In response to the urgent need for mangrove conservation, several initiatives have been launched across Southeast Asia. Government authorities with support from international organizations have designated protected areas and implemented regulations to limit mangrove destruction. Community-based conservation programs to actively engage in the restoration and management of mangrove ecosystems, enabling a sustainable symbiotic mutualism between people and their environment (Risqiani et a., 2020).

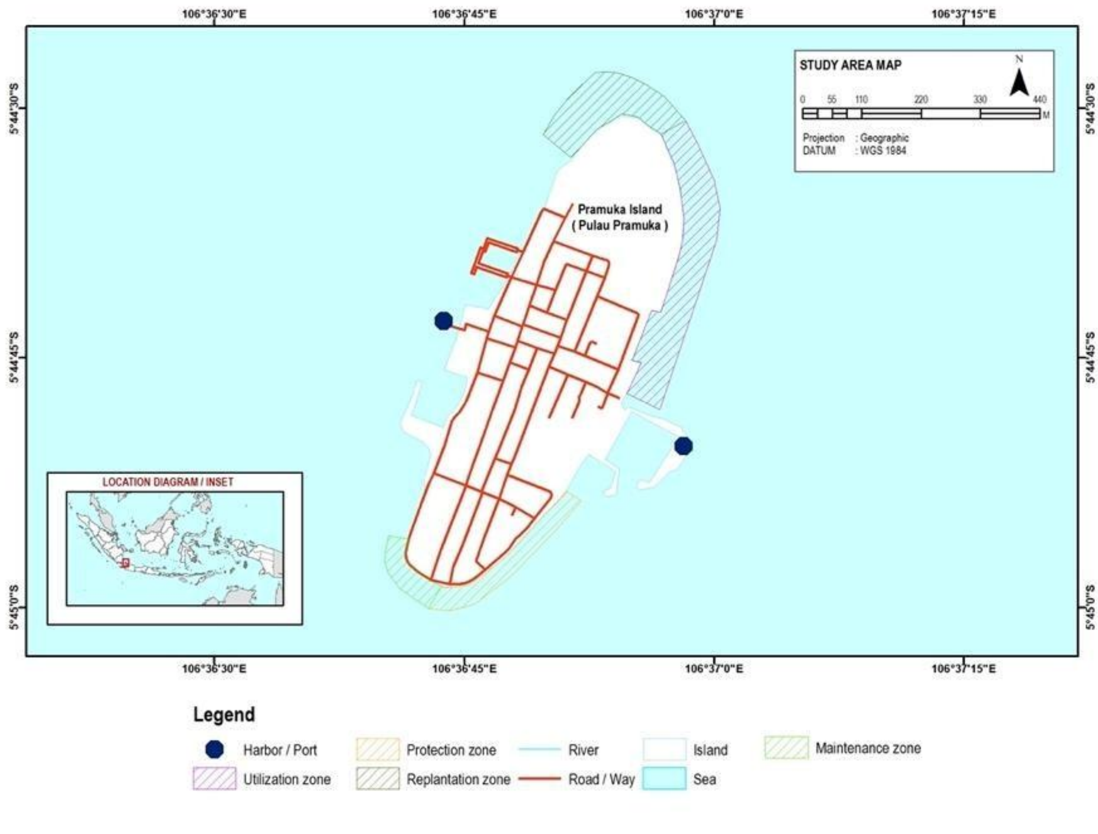

Fig. 1. Mangrove zone system

Efforts to balance development and conservation have also emerged. Innovative approaches such as strategies for building coastal infrastructure projects, such as incorporating mangrove ecosystems into the design of protection systems as breakwaters, dykes, and increasing their effectiveness in protecting the shoreline, have also emerged (Damastuti et al., 2022). Education and awareness are critical components in optimizing conservation efforts (Fan & Fan, 2024). Levels of community participation and decision-makers can make informed choices that prioritize long-term conservation (Ferraz et al., 2021; Mahajan et al., 2023; Zuniga-Teran et al., 2022). Promotion of sustainable alternatives to destructive practices such as mini-tourism, ecotourism, and research/study can help reduce pressure on mangrove ecosystems. Mangrove replanting activities should be undertaken to increase the area of existing mangroves and improve the mangrove health value index. Areas covered by mangroves need to have a zoning system (Figure 1), such as maintenance zone, utilization zone, protection zone, and replantation zone. This can help mangrove managers determine management priorities and minimize damage due to anthropogenic activities.

Zoning in principle divides the area within a conservation area into several areas to optimize the function of an area (Laitupa & Pratiwi, 2024). According to Law Number 26 of 2007 concerning Spatial Planning Article 1 Paragraph 12 formulates the definition of zoning as a form of engineering space utilization techniques through the establishment of boundaries in accordance with the potential resources and carrying capacity and ecological processes that take place as a unit. This solution can help mangrove managers determine the priority scale of management and minimize damage due to anthropogenic activities.

Research result by Adinegoro et al. (2022) The maintenance zone can be determined from the high density, as protection of residential areas on Pramuka Island, so that mangroves have the potential to grow faster. Utilization zones for tourism or pond activities can be determined from strategic areas on Pramuka Island. Protection zones can be determined from mangrove categories with seedling to sapling levels to keep seedlings to grow optimally. Replantation zones are conducted in areas that are still not planted with mangroves. The pressure to balance development and conservation of mangrove ecosystems requires a multidimensional approach that includes recognizing the intrinsic value of the ecosystem, involving local communities in conservation efforts, and exploring innovative solutions that integrate ecological considerations into development projects. Taking a sustainable and collaborative approach, the long-term conservation of mangroves can be ensured while still meeting the economic and infrastructural needs of the region.

4. Conclusions

Based on the research that has been done, it is found that mangrove diversity on Pramuka Island is still relatively low because it is dominated by one type of mangrove. Likewise, community participation in mangrove conservation is still relatively low, it is necessary to educate and increase public awareness to optimize mangrove ecosystem conservation programs. Communities need to be given concrete value to mangrove ecosystems in social and economic aspects to support their lives. Efforts to optimize mangrove ecosystem conservation in the form of a specific zoning system, divided into maintenance zones, utilization zones, protection zones, and replantation zones.

The research provides a foundation to advance understanding in the development of sustainable conservation areas both from the socio-economic aspects of the community and supporting infrastructure. There are several limitations that need to be considered. First, this study does not have macrofauna data on mangrove ecosystems that can help determine alternative programs to improve management in social, economic and environmental aspects. Second, the determination of zoning analysis as a sustainable development effort depends on subjective perceptions that may need to be studied more deeply holistically.

The simple method presented above, monitoring and evaluation should be done for improvement. Future research can be presented comprehensively from various aspects for the advancement of the above-mentioned study. Future researchers can conduct comparative studies in different regions will assess contextual differences in practice. Analyzing the relationship between sustainability variables will provide broader knowledge, as an important improvement in the optimization of mangrove ecosystem conservation areas.

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