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MANGROVE ECOSYSTEM MANAGEMENT STRATEGY FOR TUNDA ISLAND, BANTEN PROVINCE

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ABSTRACT

Mangrove ecosystems protect small islands and provide economic and social benefits to the community. Among the small islands in Indonesia with mangroves at its shorelines is Tunda Island, located in Serang District, Banten Province. However, various threats, such as shipping industrial waste and climate change, have caused the mangroves of Tunda Island to decline. This study aims to describe the condition of mangroves on Tunda Island, assess the local community's perception level of mangrove management, and formulate a strategy for managing the mangrove ecosystem on this island. This research was conducted on Tunda Island, Banten Province in January 2022. Mangrove ecological data were collected at four stations using purposive sampling, and questionnaires were distributed to collect community social data from 95 respondents. Mangrove health was analyzed using the *Mangrove Health Index* (MHI), while community social data were analyzed using the Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis and the Quantitative Strategic Planning Matrix (QSPM). Results showed that the mangroves fall into the category of poor, with an MHI of 14.75% on the north side; poor with 17.16% on the west side; moderate with 51.07% on the south side; and moderate with 65.89% on the east side of the island. The level of community perception of Tunda Island mangrove management is 60.66%, which implies a positive perception, and that the people of Tunda Island have an adequate understanding of the role of the mangrove ecosystem. The priority management strategy is to empower the community in the accelerated program to rehabilitate sustainable mangrove ecosystems by providing equal opportunities and rights for the community.

Keywords: Mangroves, Tunda Island, Management Strategy.

I. INTRODUCTION

Indonesia is an archipelagic country with various types of coastal ecosystems, including the mangrove ecosystem, which plays a significant role in protecting coastal areas. Indonesia has more than three million hectares of mangroves, located on large and small islands, with 202 recorded plant species. As an ecosystem affected by tides, mangrove vegetation has varying levels of adaptability to high salinity, low oxygen, and standing water [1]. Mangrove ecosystems also have important biological, economic, and social functions. From an ecological perspective, mangroves play a role in carbon sequestration, providing animal habitat, maintaining shoreline stability, protecting beaches from abrasion, and maintaining water quality. The economic value of mangroves ecosystems has been estimated at US$14,000–16,000/ha/year, while the global economic value reaches US$ 1.6 billion/year [2-4].

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The latest map of the national mangrove area in 2021 shows that of the 3.3 million hectares of mangroves, 19.26%, or 638 thousand hectares, is in critical condition. Indonesia's mangroves ecosystems are currently under pressure due to various threats, such as increasing illegal logging, over exploitation, land conversion, settlements, aquaculture, and domestic waste pollution [5-7]. For small islands, the mangrove ecosystem plays a vital role in protecting the island from abrasion and sedimentation so that the island is not lost [8]. Among the small islands in Indonesia that has mangroves at its shorelines is Tunda Island, located in Wargasara Village, Serang District, Banten Province. The natural beauty of Tunda island's coast has made it a tourist destination [9]. However, the vulnerable conditions of the northern coast of Banten threaten the mangroves ecosystem on Tunda Island. According to [10], Tunda Island is affected by pollution from crude oil waste from the Banten Region, which causes many mangrove trees to die.

Anthropogenic activity has caused the island's coast to accumulate marine debris from the mainland. According to [11], Tunda Island is the endpoint destination for urban waste, especially those from the estuaries of Cidurian, Ciujung, Cibanten, and Cilegon rivers. During the west season, particularly in the second to third quarters, the volume of this waste increases along with the increase in fishing and tourism activities. It is clear that the mangroves ecosystem on Tunda Island will continue to suffer damage if it is not properly managed. Therefore, this study aims to describe the condition of mangroves on Tunda Island, assess the local community's perception level on mangrove management, and formulate a mangrove ecosystem management strategy for this island.

2. RESEARCH METHOD

Time and Place

Field data were collected from December 2021 to January 2022, along the coast of Tunda Island, Banten, which has an area of 257.5 ha (Figure 1).

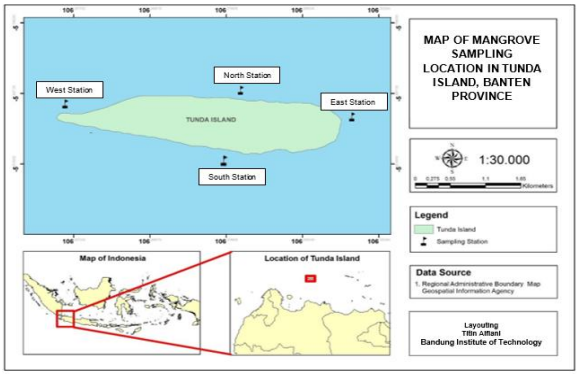

Figure 1. Location of Tunda Island and sampling stations for mangrove data collection

Method

Mangrove data were collected using the Line Transect method at four main stations, namely north, south, west, and east, determined by purposive sampling. Sampling was conducted from nested transect plots of 10 x 10 m, 5 x 5 m, and 2 x 2 m. Water quality parameters measured include temperature (^{o}C), salinity (ppt), and acidity (pH) taken at each observation station. In addition, the percentage of solid waste (trash) cover was also recorded from each sampling plot.

Data required formulating management strategies were collected through the distribution of questionnaires and interviews. The population in this study was residents of Wargasara Village, Tunda Island, and Banten. The number of respondents was determined based on the Slovin formula with an error of 10%. Respondents were selected by purposive sampling, namely residents of the Wargasara Village, Tunda Island, with minimum age of 18 years, amounting to about 95 people. Respondents were given 13 statements or questions encompassing

four aspects: socio-economic, environmental, legitimacy, and acceptability (Q1-Q12), with one general statement (Q0) related to threats to mangroves (Table 1), which were answered using a Likert scale of 1 (strongly disagree) to 5 (strongly agree). The respondents were also given open-ended questions that ask them to explain their understanding of the functions and threats to the mangrove ecosystem on Tunda Island.

Table 1. Statements related to the local community perception on mangrove management in Tunda Island

	Statements
Q0	Threats to mangroves have environmental, social, and economic impacts that are detrimental to the community
SOCIO-ECONOMIC	
Q1	The destruction of mangrove forests due to illegal actions will disrupt the socio-economic activities of the community
Q2	Local community activities also discuss the management of mangrove ecosystems
Q3	The community's economic activities depend on mangrove products (timber, fish farms, docks)
ENVIRONMENT	
Q4	Mangroves have important benefits for the coastal environment
Q5	Damage to the mangrove ecosystem will damage other environmental components
Q6	Logging and industrial waste have an impact on the sustainability of mangrove forests
LEGITIMACY	
Q7	Local ccommunity participation in the management of mangrove ecosystems by local governments (e.g., forest patrols, mangrove planting)
Q8	The government clearly explains the rules and regulations related to actions that disrupt the sustainability of the mangrove ecosystem to the community
Q9	Village regulations have regulated waste disposal and tree cutting at mangrove locations.
ACCEPTABILITY	
Q10	Communication between mangrove managers and the local community is going well
Q11	Mangrove monitoring activities have been conducted well
Q12	Handling of threats to the mangroves (mangrove tree cutting, waste) through law enforcement has been conducted well and correctly

Data Analysis

Analysis of Mangrove Cover

The percentage of mangrove cover was calculated using the hemispherical photography method [12]. This analysis separates sky pixels and vegetation covers so that the percentage of mangrove vegetation cover pixels can be calculated in binary image analysis. The captured photos were analyzed with Image software. The percentage of mangrove cover compares the number of pixels with a value of 255 (P255) with the total number of pixels (∑P) multiplied by 100%. Calculations were made on the percentage of mangrove cover in all stations. The level of mangrove health was analyzed using the *Mangrove Health Index* (MHI) developed by [12] with the following formula.

$$\textbf{MHI (\%)} = [(SC + SD + SNsp)/3] \times 10$$

Where:

S : score
C : Canopy closure (%)
D : average diameter (tree and sapling) (cm)
Nsp : sampling abundance (individual/ m^2)

Where the score is

SC = 0.25C – 13.06
SD = 0.45D + 1.42
SNsp = 0.13Nsp + 4.1

From the above formula, the MHI scores are categorized into three, namely: poor (MHI > 33.33%), moderate (33.33% < MHI < 66.67%) and good (MHI > 66.67%).

Analysis of Ecological Community Indices

The diversity index (H'), evenness index (E), and dominance index (D) were calculated using the formula of [13-14]

Analysis of Waste Cover Percentage

The percentage of waste cover at the sampling plot location was calculated by comparing the area covered with waste with the total area of the [12].

Analysis of Community Perception Level

This analysis was conducted to determine the extent of public perception of the management efforts and the condition of the mangrove ecosystem. In the analysis of Tunda Island's community perception level, the maximum perception points are five, the number of statements that must be given a perception answer is 13 (Q0-Q12), and the number of respondents is 95. Therefore, the total maximum score of community perception in this study is 6,175, namely the multiplication of maximum perception points, the number of statements, and the number of respondents. The following formula calculates the percentage level of public perception:

Total Score = the total number of points on the Likert scale of respondents' perceptions in all statements

Score Perception Level = Score/ (Maximum score) x 100%

The interpretation of the Total Score is as follows [15]:

- Quartile III < Score < Maximum means very positive (people understand very well the role of mangrove ecosystems)
- Median < Score < Quartile III, positive (people quite understand the role of mangrove ecosystems)
- Quartile I < Score < Median, meaning negative (lack of awareness about the role of mangrove ecosystems)
- Minimum<Score< Quartile I, meaning very negative (people do not understand the role of mangrove ecosystems

Respondents' characteristic categories such as village location, gender, occupation, age range, and education level were analyzed for significance using one-way ANOVA to see if there was a significant difference (sig. 0.05) from the total perception score in each category [16].

Formulation of Mangrove Ecosystem Management Strategy

The strategy for managing mangrove ecosystems was formulated using Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis and the Quantitative Strategic Planning Matrix (QSPM). This method was conducted through three stages of data analysis and implementation [17-19]: the entry stage evaluates internal and external factors owned by the management institution using the Internal Factor Evaluation (IFE) and External Factor Evaluation (EFE) matrix, the matching stage assesses the management institution's position in an internal-external (IE) matrix, and the decision stage is the stage of determining strategic priorities from alternative strategies that have been built on the SWOT matrix. At this stage, the QSPM matrix is used to evaluate the strategy objectively based on the identified internal and external factors.

3. RESULT AND DISCUSSION

Mangrove Ecosystem Condition

Mangrove Health Index (MHI)

Calculation of the Mangrove Health Index showed that Tunda Island is in the

poor to moderate category, with variation among sampling stations (Table 2).

Table 2. Mangrove Health Index of Mangrove Areas in Tunda Island

Sampling Station	C (%)	D (cm)	Nsp	Mangrove Health Index (MHI) (%)	Category
North	4.52	17.40	0.02	4.75	Poor
West	27.77	12.74	0.09	17.16	Poor
South	68.62	12.66	0.07	51.07	Moderate
East	76.56	18.12	0.09	65.89	Moderate

Description: C (%): mangrove coverage; D: average diameter = (cm); and Nsp: sapling density

The poor category is at the north and west stations, while the medium category is at the south and east stations. The health index was assessed based on a combined score of mangrove cover, average diameter, and sapling abundance. The low MHI value at the north and west stations is due to the canopy cover percentage, which is much less than the south and north stations, i.e., only 4.52% (north station) and 27.77% (west station). [20] Showed that the mangroves on Tunda Island were still in the good category or very dense, with all stations having a density of > 1,500 individuals/ha. Compared with the current study (Table 2), there has been a decline in the category of mangrove conditions. The north and west stations of Tunda Island are affected by much larger waves than the south and east stations because they are located directly opposite the Java Sea [11]. In addition, the distance between the south and east coasts to the surrounding islands is closer than the west and north stations. The proximity to other islands, especially the main island, can have an absorbing effect on waves before they finally hit the Coast of Tunda Island [21]. The island's west and north stations have extensive associated mangrove species and beach forest vegetation such as Nipa and coconuts, while not many true mangrove species are known to have grown there. The canopy closure (C) of 4.52% at the north station and 27.77% at the west station does not necessarily imply damage to the area's condition. The people of Tunda Island [22] have observed this condition of low mangrove cover for more than 50 years. The lack of mangrove cover means that the north and west stations do not have true mangrove protection, putting those areas at risk from the threat of waves and rising sea levels. Although this condition is a natural feature of the north and west sides of the island, where there are no true mangrove species and only other beach forest species, the high abrasion rate due to sea level rise has made this area a center for mangrove rehabilitation. The north station has been the target of mangrove planting sites for the past decade [23].

The average diameter of mangrove trees at the northern station is 17.40 cm, thus making the mangrove condition at the northern station larger than at other stations. The average diameter of mangrove trees at the west station is 12.74 cm, so the mangrove profile at the west station tends to be smaller. Good conditions were found at the east station, where the sapling density was 0.09 individual/m^2, with an average tree diameter of 18.12 cm. This condition supports the cover of the mangrove east station very well, with the age of the mangroves being more than one hundred years old [22]. The age of the tree will affect the physical characteristics of the mangrove; the older the age of a tree, the more likely it is to have a large diameter and a towering stature. According to [1], the height and diameter of mangrove trees contribute significantly to the area of mangrove cover.

Ecological Mangrove Community Index

Seven mangrove species were found in the mangrove area of Tunda Island,

namely *Bruguiera gymnorrhiza*, *Rhizophora mucronata*, *R. stylosa*, *R.apiculata*, *Sonneratia alba*, *Ceriops tagal*, and *C. decandra*. These findings are in line with those reported by [24] who conducted an inventory of mangroves on Tunda Island in 2018. They recorded the same species with the addition of *S.caseolaris* and *Lumnitzera racemosa* that were not found in the present study.

The diversity index (H') is 1.44, which fall into the low category and the dominance index (D) is 0.31, which is in the low category, which means that there is no dominance of one mangrove species. The evenness index (E) is 0.74, which is included in the high category, where the relative abundance of mangrove species can be said to be evenly distributed (Table 3).

Table 3. Ecological Community Index of Mangroves Species in Tunda Island

Index	Sampling Station				Average
	North	South	West	East	
Diversity (H')	0.76	1.25	1.26	0.50	0.94
Dominance (D)	0.57	0.30	0.31	0.75	0.48
Evenness (E)	0.69	0.90	0.91	0.46	0.74

Based on the results (Table 3), the three indices indicate that the mangrove community structure is still classified as good. These results show that the east side of Tunda Island is covered with only a few mangrove species, although the canopy cover is extensive. The study by [25] on the mangrove community of Tunda Island in 2018 showed that the average diversity index at the south and an east station of the island was 1.20, which is classified as low. There has not been any significant change in the last four years, but the diversity was much lower at the eastern station. According to [20] the low diversity index of a community indicates that the environmental conditions are becoming increasingly unbalanced, unstable, or depressed. The effects of climate change in coastal areas can cause this impact. Further analysis looked at the dominance and evenness of species in each sampling station. The highest dominance is at the east station; this happens because few species are found in this area compared to the mangrove area in the east, which reaches half of the total mangrove area on Tunda Island.

Water Quality Parameters

The total mangrove area of Tunda Island is 21.93 hectares or almost 10% of the total island area of 257.5 hectares. The results of water quality measurements showed that at all stations, the recorded temperature, pH, and salinity conditions were in the optimum range, except for the low average salinity at the southern station (Table 4).

Table 4. Water quality measurements in Tunda Island

Water Quality Parameters	Sampling Station				Optimum Conditions
	North	South	West	East	
Temperature (°C)	31.00 ± 0.00	31.75 ± 0,50	31.50 ± 0.71	30.75 ± 0.96	26-32*
pH	6.95 ± 0.07	6.88 ± 0.17	6.95 ± 0.21	7.08 ± 0.05	6-7.5**
Salinity (ppt)	29.00 ± 0.00	14.95 ± 0.96	21.5 ± 0.71	21.00 ± 0.82	18-30**

Tidal factors can cause low salinity values. In addition, the pH value at the south station tends to be more acidic than the other stations. This can occur because the island's south side is a residential area, and there is industrial waste pollution such

as shipping waste that covers most of the mangrove area [11].

Waste Cover Percentage

Measurement of solid waste cover in the mangrove area on Tunda Island showed that the average waste cover was 29.7%, with the south station being the location with the waste cover, i.e., 68.75%. That means that almost all the mangroves on the island's south side are covered in trash. Excessive waste cover will inhibit the growth of mangroves by changing the composition of the physical and chemical parameters of the substrate [8] (Table 5).

Table 5. Waste Cover Percentage of Mangroves in Tunda Island

Description	Sampling Station			
	North	**South**	**West**	**East**
Waste cover (%)	0.00	68.75	37.50	12.50
Average		29.69%		

According to [11], Tunda Island has become one of the endpoint destinations for marine waste due to the wind that distributes garbage. The waste comprises various domestic goods, such as used plastic, clothing, and other household industrial waste. The dominant winds that affect Tunda Island are the west and east monsoons. The dominant west monsoon movement comes from the southwest and northwest of Tunda Island, resulting in a high accumulation of waste on the southeast coast due to the influence of the wind that carries marine debris around the northern waters to the south coast. Meanwhile, the wind that blows from the northwest causes the accumulation of garbage on the south coast. The winds affect the direction of currents around the south coast and increase the speed of surface currents towards the south coast of Tunda Island. Therefore, the accumulation of marine debris on the south coast will be faster. In addition, the high amount of garbage in the south is also caused by the location of the beach, which is directly opposite large islands and residential activities. In the east season, the volume of waste on Tunda Island can reach 40 kg more than during the west season. This phenomenon is because during the east monsoon, the speed of the ocean current is higher due to the influence of the wind that moves surface currents from south to north. Therefore, in the east monsoon, the distribution of waste from Java and Lampung will be faster because waste movement occurs by currents at low tide [1,11]

Community Perception Level on Mangrove Management

Characteristics of Respondents

The people of Tunda Island are administratively under the authority of the government of Wargasara Village, Serang District, Banten Province, where the population is divided into two villages, namely West village, with two neighborhood units, and East village, with three neighborhood units. Respondents in this study consisted of 22.1% from the West village and 77.9% from the East village. The proportion of male respondents (56.8%) and female respondents (43.2%) is also balanced. The main livelihoods of the respondents are fishing (33.7%) and laborers (15.8%), while most women are housewives (34.7%). There are no aquaculture farmers operating ponds along the coast of the island. Therefore, the economy of the people of Tunda Island does not depend on mangrove products. Instead, the people of Tunda Island depend on captured fisheries for their livelihood, with the main commodity being

consumption fish or target fish from the Caesionidae family, with an average size of 15-20 cm. The average income of respondents is Rp1.125.000,-/month (Table 6).

Table 6. Characteristics of respondents from the Tunda Island community

Description	Total Respondents	%
West village	21	22.1
East village	74	77.9
Gender		
Men	54	56.8
Women	41	43.2
Age Group		
18-30 years	21	22.1
31-40 years	29	30.5
41-50 years	20	21.1
51-60 years	18	18.9
Above 60 years	7	7.4
Education Level		
No schooling	3	3.2
Primary school	55	57.9
Junior high school	24	25.3
Senior high school	12	12.6
University	1	1.1
Occupations		
Fishermen	32	33.7
Laborers	15	15.8
Housewives	33	34.7
Traders	8	8.4
Tourism actors	2	2.1
Village officials	5	5.3
Average income		
Rp1,125,000, -/month	95	100%

The 95 respondents are divided into five age classes, with the highest proportion at 31-40 years, as much as 30.5%. In general, most respondents are elementary school graduates 58%). Only 14% have advanced education to tertiary education (Table 6). A person's level of education strongly affects the level of knowledge and understanding of the community regarding ecosystem management [26-27].

Community knowledge about function and threats to mangrove ecosystems and their management. The results show that 95.8% of respondents understand the function of the mangrove ecosystem, while 4.2% of other respondents do not. The functions of the mangrove ecosystem, as generally understood by respondents, are as follows:

1. Breakwater (46.3% of respondents)
2. Prevention of tsunami, abrasion, erosion, and flood disasters (53.7% of respondents)
3. Coast guard (24.2% of respondents)
4. Fish habitat (16.8% of respondents)
5. Water filter (3.2% of respondents)

In addition, the damage to the mangrove ecosystem is dominated by natural factors such as strong waves and external factors from island communities such as shipping and industrial waste. Knowledge related to threats to mangrove ecosystems understood by respondents is as follows:

1. Crude oil waste (77.9% of respondents)
2. Strong waves (54.7% of respondents)
3. Waste (52.6% of respondents)
4. Anchors (14.7% of respondents)
5. Waste disposal by ships (7.4% of respondents)
6. The use of bombs in catching fish (3.2% of the respondents)

Forty-two percent of respondents claimed to have been involved in mangrove management, while 53% of other respondents did not. The involvement in question is participating in mangrove planting programs held by the private sector and the government. In addition, regarding the mangrove ecosystem management in Tunda Island, the results show that 83.2% of respondents know who the mangrove managers are, and 16.8% of other respondents do not know. Respondents understand that the parties who are the managers of mangroves in Tunda Island include the village government, local government, and the community. Most of the respondents who know mangrove management do not understand the regulations related to mangrove ecosystem management. This phenomenon happened because of the lack of dissemination from the government regarding the rules related to mangrove conservation.

Level of Local Community Perception

The total perception score of all respondents is 3,746, and the level of public perception is 60.66%. These values are within the median and quartile III, which means that the community perception is positive, and it is believed that the people of Tunda Island understand the role of the mangrove ecosystem. This perception is one of the main reasons why it is important to involve the community in managing mangrove ecosystems in the future. The community is enthusiastic about the mangrove-planting program held by the government and the private sector. However, the uneven distribution of population between the West village and East village often means that the West village community on the island does not get the same opportunities as the East village community, which is the center of the village government location. This issue often becomes an internal conflict during the mangrove rehabilitation program. By separating the perceptions of the people of the west and east villages, the level of perception obtained were 55.48% for the west village (in the quartile I and median ranges), and 62.60% for the east village (in the median and third quartile ranges) with a significance of 0.05 (Table 7).

These results indicate that the perception of mangrove management by the people of the west village is still less than that of the east village. This needs to be a concern later in formulating a management strategy where community empowerment will be focused on the people of the west village without reducing the level of participation of the east village community. In addition, the respondent's characteristic that significantly differs from other perceived values is gender. This means that male and female respondents gave significantly different perception values. Furthermore, the characteristics of the age group, education level, and occupation did not differ significantly in the results of people's perceptions (Table 7).

Table 7. One-Way ANOVA Statistical Test Results

Description	***Significance* (*Sig.*)**
Different Village	0.000**
Gender	0.003**
Age Group	0.102
Education Levels	0.903
Occupations	0.095

**. Significance at 0.05 or 95%

Tunda Island Mangrove Management stakeholders

Identification and categorization of stakeholders

Mangrove management in Tunda Island cannot be separated from the role of the relevant stakeholders. There are several parties directly involved in the management. The stakeholder identification process follows the results of stakeholder interviews with 15 respondents. Stakeholders are categorized based on the type of organization and the level of the organization. The organization consists of public, private, and universities, while the organizational level is divided into local, national, and government scales, be it a village, district, or province [28-29] (Table 8).

Table 8. Stakeholders' category who manages mangroves in Tunda Island

Stakeholder	Organization Type	Level
DKP Banten Province	Public	Province Government
DLHK Banten Province	Public	Province Government
Wargasara Village Government	Public	Village Government
DLHK Serang District	Public	District Government
Community	Public	Local
Academia	University	National
Company	Private	National
BRGM	Public	National
Loka PSPL Serang	Public	National
NGO	Private	National

Description: DLHK: Department of Environment and Forestry; DKP: Department of Marine Affairs and Fisheries; BRGM: Peat and Mangrove Restoration Agency; PSPL: Coastal and Marine Resources Management; NGO: Non-Government Organization

A stakeholder chart was made from these categories to determine the appropriate management strategy and provide recommendations (Figure 2).

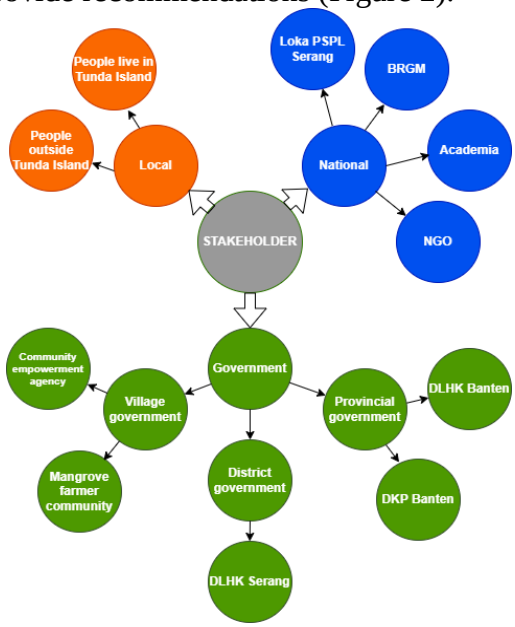

Figure 2. Stakeholders involved in mangrove management on Tunda Island

The community has a key role as the front line in mangrove conservation and is the first to be affected. The government of Wargasara Village is tasked with managing mangroves on a small scale and running mangrove conservation programs. One form of implementation of this authority, the village government, establishes a Mangrove Farmers' Community as a liaison for activities related to mangrove conservation on Tunda Island. However, until now, the village government does not have formal village documents or regulations on mangrove ecosystems' management.

The Peat and Mangrove Restoration Agency (BRGM) is tasked with conducting the national mangrove rehabilitation acceleration program, which has been mandated in the Decree of the Minister of Environment and Forestry of the Republic of Indonesia Number SK. 405/MENLHK/SETJEN/DAS.1/7/2021

Regarding the Amendment to the Minister of Environment and Forestry Number SK. 140/MENLHK/SETJEN/DAS.0/4/2021 Regarding the Work-Intensive Operational Plan for the Acceleration of Mangrove Rehabilitation in 2021, where Tunda Island is one of the targets for mangrove planting.

The Coastal and Marine Resources Management Site (LPSPL) Serang is tasked with conducting other programs from the central government, in this case, those from the Ministry of Marine Affairs and Fisheries (KKP) related to mangrove conservation with a specific allocation of funds. In addition, the private sector manages the mangrove ecosystem on Tunda Island through Corporate Social Responsibility (CSR) funds by planting mangroves. Universities, especially those close to the island, also play a role in mangrove management by researching the current condition of the Tunda Island mangroves.

The Department of Environment and Forestry of Serang District is also one of the managers of Tunda Island's mangroves, although the full authority for coastal and marine management has been delegated to the provincial government. From the Banten Provincial Government, Tunda Island mangroves are officially managed as a form of cooperation between the Department of Environment and Forestry of Banten Province and the Department of Marine Affairs and Fisheries of Banten Province. However, these two institutions do not have a routine monitoring program on the condition of mangroves, both newly planted and those already on Tunda Island. The Department of Marine Affairs and Fisheries of Banten Province has strong links with mangrove management on Tunda Island because it is related to managing coral reefs and existing seagrass ecosystems. The proposal for Tunda Island realizes this integrative management as a Regional Marine Conservation Area, which will later be formed into zoning in the coastal areas of Tunda Island. I hope that this zonation will suppress anthropogenic activities in the mangrove area. Until now, the facilities and infrastructure for monitoring mangrove ecosystems are still inadequate. This fact can be seen in the absence of specific areas for the procurement of mangrove seedlings, tools for maintaining them until they are ready for planting, and the unavailability of mangrove monitoring equipment such as personal protective equipment, GPS, and stationery. In addition, there is no allocation of funds for the maintenance of both newly planted and existing mangroves, which causes the community to have little interest in directly engaging in mangrove management because they must earn money to meet their daily needs. People also frequently take mangrove wood to be used as material for making due to problems with wood transportation from big islands. Based on Law No. 23 of 2014, provincial and regional governments have the authority to manage their regional mangrove ecosystems. The Department of Marine Affairs and Fisheries of Banten Province has a strategic position as a decision maker regarding the management of coastal ecosystems, especially the integration between mangrove ecosystems and other marine ecosystems.

Mangrove Ecosystem Management Strategy in Tunda Island

The Internal Factor Evaluation Matrix

The internal institution in this study is the Department of Marine Affairs and Fisheries of Banten Province, one of the leading institutions that have authority over managing coastal areas in Banten Province. From the multiplication of weights and rating results, the IFE score of the internal factor evaluation matrix is 2.371 (Table 9).

Table 9. Internal factor evaluation matrix

No	Factor	Weight	Rate	Score
	Strengths			
1	Good water quality and abundant mangroves species	0.122	3.600	0.441
2	Aesthetics of the sea and land panorama	0.116	3.800	0.439
3	Empowerment of the mangrove farmer community by the village government	0.116	3.400	0.393
	Weaknesses			
1	The varying conditions of mangroves require special management	0.129	2.000	0.259
2	There has never been any socialization related to the existence and importance of protecting mangroves	0.109	1.600	0.174
3	Unavailability of facilities and infrastructure to monitor the mangrove ecosystems	0.082	1.800	0.147
4	Unavailability of formal documents on mangrove management	0.116	1.200	0.139
5	Regional regulations/zoning management plans regarding marine conservation area and marine conservation management institution have not yet been established	0.102	1.800	0.184
6	The Department of Marine and Fisheries of Banten Province does not provide mangrove ecosystem monitoring activities	0.109	1.800	0.196
	Total IFE Score			**2.371**

Based on Table 9, mangrove biodiversity is the institution's most significant strength, with the highest score. At the same time, the most significant weakness factor is the condition of the mangroves, which are in the poor or damaged category.

The External Factor Evaluation Matrix

The external evaluation matrix identifies external factors from mangrove management in Tunda Island, including opportunities and threats that affect the Department of Marine Affairs and Fisheries of Banten Province in its functions. From the multiplication of weights and rating results, the IFE score of the external factor evaluation matrix is 3.030 (Table 10).

Based on Table 10, the most significant opportunity for the Department of Marine Affairs and Fisheries of Banten Province is the community perception to protect and conserve mangroves, mangrove conservation efforts by the community and the private sector, and community support to establish Tunda Island as a Regional Marine Conservation Area (KKPD) of Banten Province. This document can facilitate the government in making community-based management strategies. In contrast, the most significant threats are mangrove damage due to marine debris and water pollution by industrial waste. This threat is an essential basis for solving the problem of mangrove management on Tunda Island.

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Table 10. External factor evaluation matrix

No	Factor	Weight	Rate	Score
	Opportunities			
1	Local community perception to protect mangrove ecosystem	0.097	4.000	0.386
2	Efforts to conserve mangrove by community and company	0.097	4.000	0.386
3	Disaster mitigation program development	0.087	3.200	0.278
4	Mangroves potential as an object of ecotourism	0.082	3.600	0.296
5	Local community support for establishing Tunda Island as a marine conservation area	0.097	4.000	0.386
6	Ascertainment and Development of marine conservation area by the Regional Government	0.097	3.600	0.348
7	National mangrove rehabilitation acceleration program	0.097	3.600	0.348
	Threats			
1	Climate change	0.039	1.800	0.070
2	Damage to mangrove due to strong waves	0.048	1.600	0.077
3	Water pollution by industrial waste	0.072	1.400	0.101
4	Impacts of tourism activities	0.029	2.000	0.058
5	Abrasion and sedimentation	0.029	1.600	0.046
6	Damage to mangrove due to marine debris	0.068	2.000	0.135
7	Utilization of mangrove wood as fishing nets	0.024	1.800	0.043
8	Local community conflicts if given a mangrove conservation program	0.039	1.800	0.070
	Total EFE Score			**3.030**

The Internal External Matrix

The external and internal matrix further analyzes the internal and external evaluation matrices. This matrix is used to determine the position of the Department of Marine Affairs and Fisheries of Banten Province in making management strategies based on IFE and EFE scores. An external, internal matrix was created by looking at the quadrant relationship between IFE and EFE scores, with the total IFE score as the horizontal axis and the total EFE score as the vertical axis. The results of Tables 9 and 10, show that the total IFE score is 2.371 and the total EFE score is 3.030 (Figure 3).

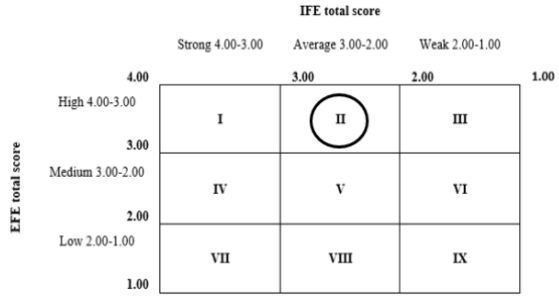

Figure 3. Internal External Matrix

Based on Figure 3, the relationship between the two scores shows that the position of the Department of Marine Affairs and Fisheries of Banten Province is in quadrant II, so the strategy that needs to be formulated is a growing and building strategy. The strategies that are suitable to be applied are those that are intensive. A SWOT matrix follows this IE matrix to formulate a more implementable strategy for managing institutions [17].

SWOT Matrix

Integrating the internal resources owned by the management institution with its external situation is an important assumption in formulating an effective strategy. The results of the integration of internal and external factors in the SWOT matrix provide ten alternative strategies, which are grouped into S-O (strengths-opportunities), S-T (strengths-threats), and W-O (weaknesses-opportunities) strategies (Table 11). The S-O strategy is formulated by using the institution's internal strengths

to maximize potential opportunities. The S-T strategy is a strategy that uses internal strengths to minimize the risk of threats. The W-O strategy is a strategy formulated by using external opportunities to improve the weaknesses of the Department of Marine Affairs and Fisheries of Banten Province. Finally, the W-T strategy is a strategy that avoids threats and reduces weaknesses. In addition, the formulation of the SWOT strategy has been matched with the main tasks and functions of the Department of Marine Affairs and Fisheries of Banten Province (Table 11)

Table 11. SWOT matrix for mangrove ecosystem management on Tunda Island

External conditions Analysis / **Internal conditions analysis**	***Opportunities*** Local community perception to protect mangrove ecosystem Efforts to conserve mangrove by community and company Disaster mitigation program development Mangroves potential as an object of ecotourism Local community support for establishing Tunda Island as a marine conservation area Ascertainment and Development of marine conservation area by the Regional Government National mangrove rehabilitation acceleration program	***Threats*** 1. Climate change 2. Damage to mangrove due to strong waves 3. Water pollution by industrial waste 4. Impacts of tourism activities 5. Abrasion and sedimentation 6. Damage to mangrove due to marine debris 7. Utilization of mangrove wood as fishing nets. 8. Local community conflicts if given a mangrove conservation program
Strengths 1. Good water quality and abundant mangroves species 2. Aesthetics of the sea and land panorama 3. Empowerment of the mangrove farmer community by the village government	**S-O Strategy** 1. Developing the large wave barrier system on the north and west side in Tunda Island (S1, S2, S3, O1, O2, O4) 2. Developing natural disaster mitigation programs in coastal areas and small islands (S1, S2, S3, O3) 3. Accomplishing routine monitoring of both newly planted and existing mangroves (S1, S2, S3, O1, O2, O5, O6)	**S-T Strategy** 1. Accomplishing the proper mangrove rehabilitation on the north and west sides in Tunda Island (S1, S2, S3, T1, T2, T3, T5, T6) 2. Arranging the waste cleaning program (S1, S2, S3, T1, T3, T4, T6)
Weaknesses 1. The varying conditions of mangroves require special management 2. There has never been any socialization related to the existence and importance of protecting mangroves 3. Unavailability of facilities and infrastructure to monitor the mangrove ecosystems 4. Unavailability of formal documents on mangrove management 5. Regional regulations/zoning management plans regarding	**W-O Strategy** 1. Empowering the local community in the sustainable mangrove rehabilitation program by providing equal rights and opportunities for the community (W1, W2, W6, O1, O2, O7) 2. Encouraging the provincial government to designate the Tunda Island as the KKPD for Banten Province and establishing its management unit (W1, W4, W5, W6, O5, O6) 3. Inventorying the supporting facilities and infrastructure for mangrove ecosystem	**W-T Strategy** 1. Increasing supervision regarding logging of mangroves by the community (W1, W2, W4, W5, W6, T7)

marine conservation area and marine conservation management institution have not yet been established 6. The Department of Marine and Fisheries of Banten Province does not provide mangrove ecosystem monitoring activities	conservation (W1, W3, W8, O6) 4. Collaborating with the private sector in the implementation of mangrove management programs, both planting, and monitoring (W1, W3, O2, O7)	

Based on Table 11, three priority strategies are obtained that have the highest Total Attractiveness Score (TAS), namely: (1) Empowering the local community in the sustainable mangrove rehabilitation program by providing equal rights and opportunities for the community; (2) Accomplishing the proper mangrove rehabilitation on the north and west sides in Tunda Island; and (3) Accomplishing routine monitoring of both newly planted and existing mangroves.

4. CONCLUSION

Results of this study showed that the condition of mangroves on Tunda Island fall into the category of poor with an MHI of 14.75% on the north side; poor with 17.16% on the west side; moderate with 51.07% on the south side; and moderate with 65.89% on the east side of the island. Seven mangrove species were found during the study, with diversity index (H') of 1.44, dominance index (D) of 0.31, and evenness index (E) of 0.74. The average percentage of solid waste cover is 29.7%, with the south station being the most waste covered, at 68.75%. The level of community perception of Tunda Island on managing the mangrove ecosystem is 60.66%, which means that the people of Tunda Island understand the role of the mangrove ecosystem. Three priority strategies formulated through this study focuses on community empowerment, rehabilitation, and routine monitoring.

Suggestions from this research are to integrate mangrove management with village regulations and revive mangrove farmer groups to support rehabilitation and monitoring activities.

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