

Integrated coastal management strategies to enhance biodiversity conservation in Karimunjawa National Park, Jepara, Central Java, Indonesia

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Abstract. *Suryanti S, Muskananfola MR, Febrianto S, A'in C. 2025. Integrated coastal management strategies to enhance biodiversity conservation in Karimunjawa National Park, Jepara, Central Java, Indonesia. Biodiversitas 26: 3011-3020.* The Karimunjawa National Park area in Jepara, Central Java, Indonesia, boasts various coastal resources and ecosystems, including mangroves, seagrasses, and coral reefs, which serve as habitats for several important organisms. Therefore, a coastal area management strategy is needed to maintain the sustainability of coastal resources. This study focuses on efforts to preserve and conserve biodiversity, especially protected biota in the Karimunjawa National Park area. This research was conducted on three islands representing each ecosystem: Kemujan Island for the mangrove area, Cemara Kecil Island for the seagrass area, and Menjangan Besar Island for the coral reef area. The research method used is quantitative descriptive. The primary data used in this study comprise biota inventory data and environmental parameters collected from each island, representing each ecosystem. Data analysis employs a community structure formula to calculate uniformity, diversity, and dominance indices, as well as a SWOT analysis to inform management strategies. The results show that the diversity index (H') is moderate, the uniformity index (e) is relatively stable, and the dominance index (C) does not contain a dominant species. Environmental parameters are also still suitable for the life of biota associated with the ecosystem. The coastal management strategies that can be implemented in Karimunjawa National Park are in quadrant 1. These strategies capitalize on the area's existing strengths and leverage its opportunities.

Keywords: Coral Reef, mangrove, protected biota, seagrass, sustainability

INTRODUCTION

Coastal areas are ecosystems that play a crucial role in human life, with two-thirds of the world's population residing in coastal areas (Suryanti et al. 2019; Simões et al. 2022). In addition, coastal areas are home to various ecosystems, including mangroves, seagrass beds, coral reefs, and various biota that inhabit these habitats (Salimi et al. 2021; Ng and Ong 2022; Kalidi et al. 2023). Dynamic coastal environmental conditions and diverse uses of coastal areas can lead to environmental degradation and losses for communities and governments (Dey et al. 2021; Sabdaningsih et al. 2023). One of the losses caused by environmental degradation is the extinction of several species. Coastal changes not only threaten aquatic species with extinction through habitat loss and degradation but also alter nutrient cycles and increase the likelihood of peatland collapse (Hughest 2017).

Indonesia ranks fourth out of 20 countries in terms of biodiversity extinction risk, with 1,126 species threatened with extinction. Biodiversity conservation efforts, both in situ and ex-situ, have proven to be ineffective. According to the Ministry of Environment and Forestry of the Republic of Indonesia (2015), at least 27 million hectares of land have been declared as protected areas. Karimunjawa National Park is one of 51 designated national parks that are suitable for protection due to environmental concerns. Activities in Karimunjawa

National Park that threaten the environment include converting mangrove areas into ponds, planting coconut trees, polluting the water with pond waste, harvesting protected species for food and souvenirs, and building new tourist attractions.

The big islands of Karimunjawa National Park, such as Karimunjawa Island and Kemujan Island, are in danger due to the devastation of the mangrove ecosystem. According to the findings of Kamal et al. (2016), the area of mangrove forests on these two islands experienced degradation of 23.8 Hectares between 2009 and 2012 due to changes in land use for shrimp and fishponds, as well as coconut tree planting. Likewise, the hard coral cover in the coral reef environment of Karimunjawa National Park decreased from 57.86% in 2013 to 49.89% in 2016. This decrease is attributed to coral bleaching, a phenomenon caused by global warming, which resulted in increased sea surface temperatures globally between 2015 and 2016.

Coral reef ecology supports the diversity of marine biota. One of the biotas that live in coral reefs is crocus clams (*Tridacna crocea*). Crocus clams is an animal protected by Indonesian Government Regulation Number 7 of 1999 concerning the Preservation of Plant and Animal Species, and its population has decreased on three islands in Karimunjawa National Park, consisting of Geleang Island, Cemara Besar Island, and Menjangan Besar Island. Apart from shellfish, the sea cucumber population has also decreased. The results of monitoring sea cucumbers at

Karimunjawa National Park in 2016 showed that there were 166 sea cucumbers, which is less than the 315 sea cucumbers recorded in 2012.

Karimunjawa National Park features a seagrass habitat, one of the most productive coastal ecosystems, alongside coral reef ecosystems and mangrove forests. According to Fafurida et al. (2020), the seagrass ecosystem has a more diversified form of macroalgae. Seagrass grows to a depth of 25 meters in the waters of Karimunjawa National Park. As one of the biotas inhabiting seagrass beds, sea urchins are often seen in mixed seagrass habitats. This condition is mainly caused by sea urchins that live, breed, and feed in the seagrass ecosystem (Suryanti et al. 2024).

The degradation of mangroves, seagrass, and coral reefs, as well as the decline in marine biota populations, are indicators that the Karimunjawa National Park needs to intensify its conservation efforts. According to Kennedy et al. (2020), the numerous threats that disrupt coastal ecosystems lead to a decline in the quantity and quality of these ecosystems. Local factors, such as poor water quality, disease, coastal development, invasive species, overfishing, and destructive fishing techniques, can all impact coral reefs. However, over the last 30 years, climate change, particularly ocean warming, has been the primary driving factor contributing to their decline and extinction.

Therefore, a coastal management strategy is significantly required as an effort to conserve biodiversity, maintain the sustainability of ecosystem conditions, and support the lives of protected rare organisms. Based on this phenomenon, the purpose of the study is to assess the condition of the ecosystem and the diversity of associated biota in the Karimunjawa National Park Area and to develop a coastal management strategy that supports the

sustainability of the ecosystem and the survival of protected organisms on the verge of extinction.

MATERIALS AND METHODS

Study area

The study was conducted in Karimunjawa Sub-district, Jepara District, Central Java, Indonesia. The Karimunjawa Islands are located at the following geographical coordinates: 5°40'-5°57' South Latitude and 110°04'-110°40' East Longitude. This study covers Kemujan Island for the mangrove area, Cemara Kecil Island for the seagrass area, and Menjangan Besar Island for the coral reef area. This island was chosen because it represents the ecosystems that are the focus of the research area: mangroves, seagrass, and coral reefs. Additionally, the number of visits to the island was a factor in selecting the research location. The research location can be seen in Figure 1 below.

Procedures

Research method

The research method used is quantitative descriptive. This method is designed to create a comprehensive and objective representation of a particular situation, utilizing numerical data, and using a systematic approach in data collection, analysis, and interpretation. The purpose of the study is to obtain a picture of the phenomenon and describe it systematically, with a focus on factual data rather than conclusions.

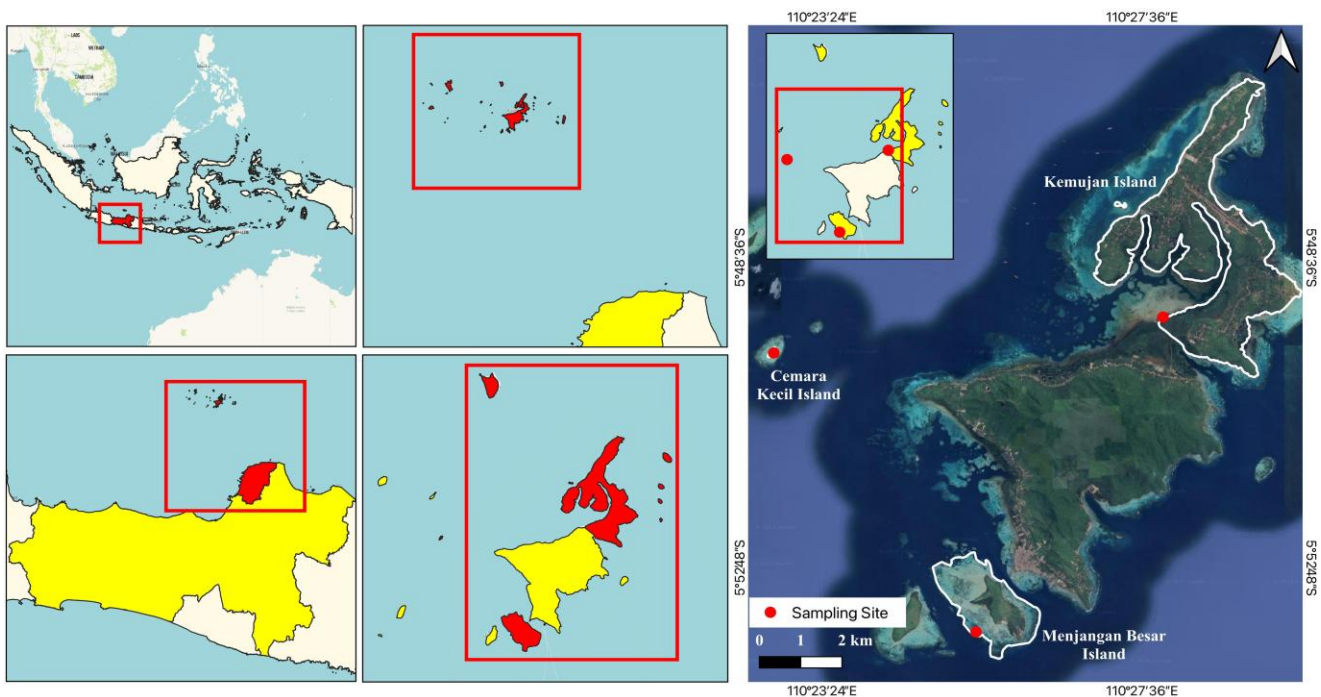


Figure 1. Research locations in Karimunjawa Sub-district, Jepara District, Central Java, Indonesia: Kemujan Island, Menjangan Besar Island, and Cemara Kecil Island

Data collection

The data in this study were collected using purposive sampling techniques. The data needed includes secondary data sourced from the Karimunjawa National Park Office, which discusses the abundance of several types of biotas. This secondary data can later be used to validate protected biota data found at the research location. Validation was carried out by matching the biota found in the field with the biota data held by Karimunjawa National Park.

The primary data used in this study include biota inventory data collected from each island representing each ecosystem: Kemujan Island for the mangrove area, Cemara Kecil Island for the seagrass area, and Menjangan Besar Island for the coral reef area. Mangrove data collection was on Kemujan Island, with 3 stations with 3 plots. These three stations were carried out by making a plot of 10x10 meters and measuring the Diameter at Breast Height (DBH) (Zanvo et al. 2023). Sampling locations in the mangrove ecosystem were conducted in the mangrove tracking area.

Coral reef data collection was conducted on Menjangan Besar Island using the Line Intercept Transect (LIT) method commonly used in coral reef methods (Facon et al. 2016) with a line stretched along 50 meters at 3 points, so that the line stretched in the station was up to 150 meters. Coral reef sampling locations were selected in snorkeling areas with extensive coral reef habitats.

Seagrass data collection was conducted on Cemara Kecil Island by stretching a 50-meter transect line at 3 points. Data collection was carried out using a 50x50 cm quadrant that has 4 spaces measuring 25x25 cm. Sampling locations were in the Cemara Kecil area, which has a seagrass ecosystem.

Water quality data collection includes salinity taken using a refractometer, DO using a DO meter, pH and temperature using a pH meter, carried out at each station. In addition, questionnaire data are also needed for 10 sources consisting of Karimunjawa National Park staff, the community, organizations engaged in the environmental sector, tourism managers, and academics.

Data analysis

The types of species were obtained from three coastal ecosystems: mangroves, coral reefs, and seagrass beds. The organisms were photographed, and the abundance, diversity, uniformity, and dominance values were calculated using the formula.

Diversity Index (H') uses the formula (Odum 1971):

$$H' = - \sum_{i=1}^s \frac{n_i}{N} \ln \frac{n_i}{N}$$

Where,

n_i : Number of species

N : Total number of individuals

Uniformity Index using the formula (Odum 1971)

$$e = \frac{H'}{H_{maks}}$$

Where,

e : Uniformity Index

H : Shannon-Weaver Diversity Index

H_{max} : $\ln S$

S : Number of Species

Dominance Index

$$C = \sum \left(\frac{n_i}{N} \right)^2$$

Where,

C : Dominance index

n_i : Number of individuals of the i -th species

N : Total number of individuals

Coastal management strategy determination is analyzed using the SWOT analysis method. Rating values are given based on strengths and opportunities, where a score of 4: strongly agree to a score of 1: disagree. This is inversely proportional to the weakness and threat factors, with a score of 4: disagree to a score of 1: strongly agree. After that, calculate on the Internal Factors Analysis Summary (IFAS) and External Factors Analysis Summary (EFAS) matrices to determine the final weight, rating, and score. Further calculations of internal and external factors can be illustrated with a cartesian diagram of the IFAS and EFAS calculation scores. The use of the SWOT method in designing coastal management strategies was chosen because the SWOT analysis considers internal and external aspects of a project, so that by knowing these 2 things, it is expected to be able to provide a more appropriate management strategy for the internal and external aspects of a coastal project.

RESULTS AND DISCUSSION

Biota found in mangrove, seagrass, and coral reef ecosystems

The results of research in the mangrove ecosystem located on Kemujan Island, seagrass beds located on Cemara Kecil Island, and the coral reef ecosystem on Menjangan Besar Island, Karimunjawa National Park, produced results as presented in Table 1. In the mangrove ecosystem, the most abundant biota found are Gastropods from the species *C. quadrata*, *T. telescopium*, *T. leporina*, *T. sulcata*, *G. tumidum*, *C. rugifera*, *C. decollata*, *A. caerulea*, *C. currani*, and *T. elata*. The most abundant biota in the seagrass ecosystem is Echinodermata, consisting of the species *H. leucospilota*, *E. sepositus*, *L. laevigata*, and *E. mathaei*. The composition of biota in the coral reef ecosystem found during the study consisted of Echinodermata from the species *L. laevigata*, *A. polyacanthus*, *C. bella*, and *O. ophiactoides*.

Discovered protected biota species

Based on the results of the research conducted, the protected biota found in the Karimunjawa National Park area include sand clams (*H. hippopus*), crocus clams (*T. crocea*), and nile trochus (*T. Niloticus*). Protected biota are animals that are in danger of extinction and/or have a small population. Protected animals may not be owned, traded, or kept either alive or dead, intact, or only as body parts, or have become other items such as jewelry. According to

Ibrahim et al. (2023), low awareness of biodiversity and conservation, as well as conflicts with authorities, have led to problems such as pollution, biota extinction, and ecosystem degradation. Protection of biota is important to support conservation efforts to prevent extinction. These protected biota or animals are regulated by law and are protected internationally, one of which is through Government Regulation Number 7 of 1999. One of the international organizations dedicated to the conservation of natural resources is the International Union for Conservation of Nature and Natural Resources (IUCN). Table 3 shows that the condition of the waters at the research location is still suitable for the habitat of benthic biota. However, the number of protected biotas at the research location is decreasing due to hunting for consumption and souvenir-making, as well as changes in land use that affect their habitat.

Table 1. Biota found at sampling locations

Location	Species	Number
Mangrove ecosystem (Kemujan Island)	<i>Crassostrea gigas</i>	7
	<i>Laganum laganum</i>	11
	<i>Conus lividus</i>	5
	<i>Mespilia globulus</i>	1
	<i>Bradybaena similaris</i>	2
	<i>Laganum retinens</i>	18
	<i>Laganum boschi</i>	16
	<i>Laganum depressum</i>	22
	<i>Nassarium concinus</i>	5
	<i>Peryglypta reticulata</i>	6
	<i>Cerithidea quadrata</i>	41
	<i>Telescopium telescopium</i>	63
	<i>Trona leporina</i>	2
	<i>Terebralia sulcata</i>	67
	<i>Meretrix meretrix</i>	5
	<i>Gafrarium tumidum</i>	4
	<i>Codakia rugifera</i>	2
	<i>Cerithidea decollata</i>	29
	<i>Albinaria caerulea</i>	46
	<i>Crassispira currani</i>	7
Seagrass bed (Cemara Kecil Island)	<i>Kukrimon cucphuongensis</i>	1
	<i>Throcoidea elata</i>	6
	<i>Ciliopagurus strigatus</i>	1
	<i>Scylla serrata</i>	2
	<i>Hippopus hippopus</i>	3
	<i>Holothuria leucospilota</i>	9
	<i>Pinna rudis</i>	11
	<i>Echinaster sepositus</i>	3
	<i>Conus marmoreus</i>	6
	<i>Linckia laevigata</i>	2
	<i>Echinometra mathaei</i>	2
	<i>Spisula solida</i>	8
	<i>Corythoichthys sp.</i>	1
Coral reef ecosystem (Menjangan Besar Island)	<i>Lambis crocata</i>	6
	<i>Hippopus hippopus</i>	5
	<i>Tridacna crocea</i>	1
	<i>Trochus niloticus</i>	2
	<i>Linckia laevigata</i>	4
	<i>Culcita sp.</i>	3
	<i>Astropecten polyacanthus</i>	2
	<i>Cenometra bella</i>	2
<i>Ophiocomella ophiactoides</i>	2	

Community structure analysis

The results of calculating the structure of the biota community at the research location can be seen in the Table 2.

Uniformity index (e)

The uniformity index (e) value obtained from the three research locations shows that the distribution pattern of species at the research location is quite even, indicating that the community is in a stable condition. According to Suwartimah et al. (2017), the uniformity index value, if it approaches zero, indicates the ecosystem is susceptible to species dominance as a result of an imbalance between population and environmental conditions. Based on the standard value of Odum (1993), the standard value of the evenness index $0 < E < 0.5$ is classified as Distressed, $0.5 < E < 0.75$ is classified as unstable and $0.75 < E < 1$ is classified as stable.

Diversity index (H')

The diversity index values obtained from the three research locations show that these three ecosystems have a moderate level of diversity. The diversity index (H') is an index value that can determine the level of diversity of a species in an area with a range of values from 1 to 3, which is indicated by the higher the diversity value obtained, the more diverse the diversity value of a species in a particular area, so that it can be used to assess the status of diversity, evenness, and richness of species (Roy et al. 2022). Based on Odum's standard values (1993), the diversity value index $H < 2$ is classified as low, $2 < H < 3$ is classified as moderate, while $H > 3$ is classified as high.

Dominance index (C)

The dominance index (C) obtained indicates that there is low dominant species because the value obtained is not close to 1. This suggests a relatively balanced community structure with a more equitable distribution of species abundances, which is a positive ecological indicator. A low dominance index implies higher biodiversity and reduced vulnerability to environmental disturbances. Diverse communities tend to be more resilient and better able to recover from external stresses such as climate variability, human disturbance, or pollution. This is because the index approaches 1, it indicates an increasing dominance or concentration of one or a few highly abundant species, reducing the overall diversity of the community (Kitikidou et al. 2024). Based on Odum's (1993) standard values, the standard value of the dominance index $0 < C < 0.5$ is classified as low, $0.5 < C < 0.75$ is classified as medium and $0.75 < C < 1$ is classified as high.

Environmental parameters

Environmental parameter measurements were conducted at each observation station, i.e., on Kemujan Island, Cemara Kecil Island, and Menjangan Besar Island. The environmental parameters observed were temperature, salinity, pH, DO, and substrate from the mangrove, seagrass, and coral reef environments. The measurement results of all parameters showed values that were still

feasible for the survival of aquatic organisms. Because environmental factor measurements were conducted at the time of biota sampling, some measurements depend on the time of day (morning or afternoon) due to constraints in the field sampling schedule. Measurement of environmental factors at the research location can be seen in the Table 3.

Based on the results of environmental parameter measurements at three research locations, namely Kemujan Island, Cemara Kecil Island, and Menjangan Besar Island, there were significant variations in the standard quality of seawater for marine biota according to Government Regulation No. 22 of 2021. Temperature parameters on Kemujan Island reached 40°C, far exceeding the required standard limit of 28-32°C, which could potentially cause thermal stress to marine life, especially coral reefs, and fish. Meanwhile, the temperature on Cemara Kecil Island (32.9°C) slightly exceeded the upper threshold, and the temperature on Menjangan Besar Island (30°C) remained within the permissible range. According to Ighwerb et al. (2021), a temperature of 26-30°C is included in the optimum temperature range for the growth of marine biota.

In terms of salinity, Kemujan Island showed a value of 40‰, which significantly exceeded the quality standard limit of 32-34‰. In contrast, salinity on Cemara Kecil Island (32‰) and Menjangan Besar Island (30‰) was relatively close to or slightly below the established lower limit. Salinity is one of the environmental parameters that has a significant influence on the existence of echinoderms. However, each species of echinoderm has a different tolerance to salinity.

The pH parameter on Kemujan Island (8.3) is still within the normal range (7.0-8.5), but the pH values on Cemara Kecil Island (8.7) and Menjangan Besar Island (8.6) slightly exceed the upper threshold, which may affect the physiological processes of certain marine organisms.

For Dissolved Oxygen (DO) parameters, all locations showed values above the minimum threshold of 5 mg/L, with Pulau Cemara Kecil recording the highest value of 14.6 mg/L, which, although considered good, could also be an indication of potential eutrophication if left uncontrolled.

The basic substrate variation in the water at the three research locations was the same, i.e., muddy sand and coral sand. The similar substrate variation among the three study sites resulted in the number of individuals of each echinoderm species found being not significantly different, so the species diversity index at the three study sites did not differ significantly. According to Suryanti et al. (2016), the distribution of local marine fauna is influenced by habitat, substrate, depth, and zoning.

In general, these results indicate that Menjangan Besar Island is the location that most closely approximates ideal environmental conditions for marine biota, while Kemujan Island shows the most significant deviation from marine water quality standards, thus requiring special attention in the context of conservation and coastal environmental management. As mentioned earlier, environmental factor measurements were conducted at the time of marine life sampling, so some measurements depend on the time of day (morning or afternoon).

Management strategy

SWOT analysis includes internal factors (strengths and weaknesses) and external factors (opportunities and threats). Internal and external SWOT factors can be seen in the Table 4. Calculations on the Internal Factor Analysis Summary (IFAS) matrix are used to see calculations through the weight of values and scores given by respondents in internal factors. The calculation of the IFAS matrix is shown in Table 5.

Table 2. Results of uniformity, diversity, and dominance index calculation

Ecosystem	Station	Uniformity index	Diversity index	Dominance index
Mangrove	1	0.18743	1.87426	0.17726
	2	0.28925	1.15699	0.37278
	3	0.25814	1.29070	0.32944
Seagrass	1	0.20567	2.05677	0.15074
	2	0.19584	2.15433	0.13295
Coral reefs	1	0.94064	2.06680	0.14128

Note: Research data (2024)

Table 3. Results of environmental factor measurements at the study location

Location	Environmental parameters				
	Temperature (°)	Salinity (%)	pH	DO (mg/L)	Substrate
Kemujan Island (Mangrove)	40	40	8.3	6.4	Muddy sand
Cemara Kecil Island (Seagrass)	32.9	32	8.7	14.60	Muddy sand
Menjangan Besar Island (Coral reef)	30	30	8.6	5	Coral sand
Quality standards for biota*	28-32°	32-34 %	7-8.5	> 5 mg/L	

Note: Research data (2024), *Appendix VIII Government Regulation of The Republic of Indonesia Number 22 of 2021 concerning the implementation of environmental protection and management, sea water quality standards for biota

Table 4. Internal and external factors

No.	Strengths	No.	Weaknesses
1	There is a connectivity between coastal ecosystems (mangrove ecosystems, seagrass beds, and coral reefs), which is in good condition (S1)	1	Lack of access to information in public areas regarding the prohibition of taking protected biota, critical habitat destruction, and fulfillment of the requirements for implementing diving tourism that does not damage coral reefs (W1)
2	There is collaboration between the Karimunjawa National Park area management, the community, the government, and NGOs in implementing ecosystem conservation efforts and protecting endangered biota (S2)	2	The impact of the involvement of regional managers in efforts to raise awareness among the community and tourists regarding the importance of preserving coastal ecosystems is still less than optimal (W2)
3	Implementation of the use of coastal zones in accordance with established zoning regulations and the determination of zoning that is in accordance with the designation and potential of the zoning area (S3)	3	There are several location points for the construction of coastal buildings erosion and accretion control that are less than optimal (W3)
4	Adequate mobility facilities and access as well as efforts to dispose of waste from mobilization and industrial activities that can be tolerated by nature (according to quality standards) so as not to worsen environmental degradation (S4)	4	The implementation of monitoring protected biota is still less than optimal, and the form of stakeholder collaboration in monitoring biota habitat areas is still not well structured (W4)
5	Enforcement to ensure legal certainty and the realization of justice for the ecological and socio-economic aspects takes place continuously in dynamic conditions (S5)	5	The implementation of key biota diversity inventory activities is still not being carried out optimally (W5)
No.	Opportunities	No.	Threats
1	The attraction of Karimunjawa National Park is able to attract the interest of various parties, starting from the central government, NGOs, and international environmental organizations in working together to manage the sustainability of Karimunjawa National Park, which is demonstrated through the commitment to prepare a management plan for Karimunjawa National Park (O1)	1	The phenomenon of climate change is increasing along with the increase in various activities that produce waste, thus encouraging environmental degradation and shifting of biota habitats (T1)
2	There are various forms of funding activities sourced from various non-government parties in order to support the sustainability of the Karimunjawa National Park ecosystem and coastal resources (O2)	2	Lack of attention and resolution of conflicts related to coastal area management, especially in land use issues and the development of designated areas for certain areas (T2)
3	The condition of the coastline changes, which are quite stable and not too significant, still open opportunities for management and development into tourist attractions by the community and government (O3)	3	Loss of habitat for protected and endangered animals in coastal ecosystems such as mangroves, seagrass beds, and coral reefs (T3)
4	There is an agendum for reporting the results of studies related to the natural conditions of the Karimunjawa National Park coast carried out by various parties outside the government, which can be used as a reference for the management of the Karimunjawa National Park coastal area by the relevant government (O4)	4	The shift in the main livelihoods of coastal residents due to the decline in the potential of natural resources and fisheries along with environmental degradation (T4)
5	The involvement of external NGOs in implementing conservation activities can increase community participation in preserving coastal ecosystems (O5)	5	The downstream business carried out in Karimunjawa National Park prioritizes economic movement over ecosystem sustainability (T5)

Calculations on the External Factor Analysis Summary (EFAS) matrix are used to see calculations through the weight of values and scores given by respondents in external factors. The calculation of the EFAS matrix is shown in Table 6.

Factor calculation can be illustrated with a Cartesian diagram to group strategic factors that can be used in formulating further management steps. The result of the

coordinate point calculation is located at point (0.39; 0.56). The form of the Cartesian diagram is shown in the Figure 2 below.

Quadrant 1 shows the potential strengths and opportunities of coastal ecosystem conditions and associated biota conditions on Kemujan Island, Cemara Kecil Island, and Menjangan Besar Island. The combination of these strategies is shown in the Table 7.

Table 5. The IFAS matrix calculation

No.	Strength	Amount of data	Weight	Rating	Score
1	S1	35	0.126	4	0.441
2	S2	36	0.129	4	0.466
3	S3	30	0.108	3	0.324
4	S4	26	0.094	3	0.243
5	S5	31	0.112	3	0.346
The total of strengths		158			1.82
No.	Weakness	Amount of data	Weight	Rating	Score
1	W1	27	0.097	3	0.262
2	W2	24	0.086	2	0.207
3	W3	22	0.079	2	0.174
4	W4	23	0.083	2	0.190
5	W5	24	0.086	2	0.207
The total of weaknesses		120			1.04
The total of IFAS		278	1		

Table 6. The EFAS matrix calculation

No.	Opportunity	Amount of data	Weight	Rating	Score
1	O1	36	0.138	4	0.497
2	O2	32	0.123	3	0.392
3	O3	28	0.107	3	0.300
4	O4	31	0.119	3	0.368
5	O5	32	0.123	3	0.392
The total of strengths		159			1.95
No.	Threat	Amount of data	Weight	Rating	Score
1	T1	16	0.061	2	0.098
2	T2	16	0.061	2	0.098
3	T3	24	0.092	2	0.221
4	T4	22	0.084	2	0.185
5	T5	24	0.092	2	0.221
The total of weaknesses		102			0.82
The total of EFAS		261	1		

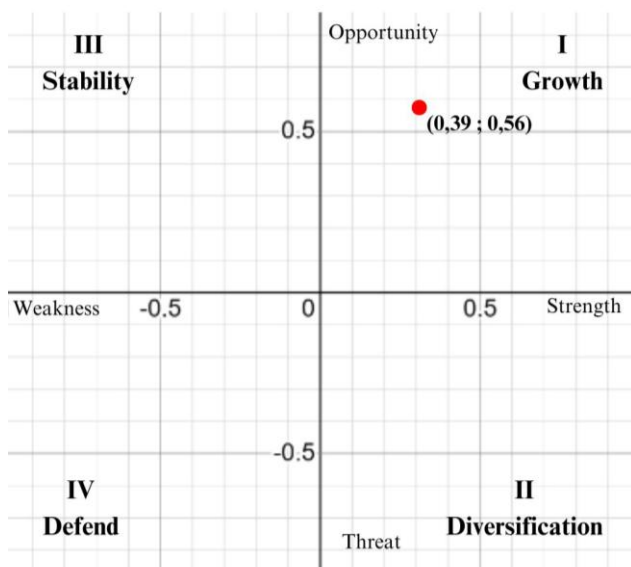


Figure 2. Cartesian diagram

The main priority of coastal management strategies that can be implemented based on the cartesian diagram is in quadrant 1 by combining strength factors with opportunities, which can be seen in Table 7. The main focus of this strategy includes promoting coastal ecosystems (mangroves, seagrass beds, and coral reefs) through social media as a means of conservation-based tourism education, as well as controlling the use of coastal areas by considering the balance between economic and ecological aspects. Additionally, this strategy emphasizes the importance of land use monitoring in accordance with zoning regulations, managing erosion prone areas based on coastal physical characteristics, and improving access while controlling industrial waste. This is consistent with research by Muhammad and Mardiatno (2023), who found that shoreline changes on Karimunjawa and Kemujan Islands tended to be stable, and it can be used as a conservation and tourism area. Multistakeholder collaboration involving the government, communities, managers, and NGO's is a key element in creating a business and tourism environment oriented toward sustainability. This is in line with the research of Abdullah

et al. (2014), which recommends an adaptive co-management approach involving local communities, government agencies, and NGOs for future management to improve mangrove sustainability in Malaysia.

After reviewing the SWOT strategy based on the quadrant and the combination of IFAS and EFAS,

alternative strategies and policies can be formulated as alternative coastal management strategies. Alternative strategies are formulated based on the ranking derived from the total score so that they are sorted based on priority level to non-priority. Alternative strategies based on SWOT are shown in Table 8.

Table 7. SWOT matrix strategy combinations

IFAS EFAS	Strength (S1, S2, S3, S4, S5)	Weakness (W1, W2, W3, W4, W5)
Opportunity (O1, O2, O3, O4, O5)	<p>(SO1) Optimizing social media branding in promoting the natural beauty and conservation activities between coastal ecosystems (mangrove, seagrass, and coral) for tourist education and as an effort to create sustainable tourism (S1, S2, O1, O2, O4, O5)</p> <p>(SO2) Create a strategy for controlling activities in coastal areas so that utilization always takes into account economic and ecological aspects that are equitable (S1, S2, S3, S5, O1, O4, O5)</p> <p>(SO3) Further examine the coast that is prone to erosion and accretion so that it can be managed properly by paying attention to the type of sediment, coastal slope, and oceanographic conditions of the surrounding waters (S1, S2, O3, O5)</p> <p>(SO4) Tightening permits and supervision of land use by communities, government, and NGOs to always comply with zoning regulations so that the economic sector always goes hand in hand without damaging coastal ecology (S1, S2, S3, S5, O5)</p> <p>(SO5) Optimizing mobility facilities and access and tightening supervision in the management of mobilization and industrial waste so that the environmental capacity and tolerance for waste are always maintained (S2, S4, S5, O1, O2, O5)</p> <p>(SO6) Optimizing cooperation between the roles of managers, government, community, and NGOs to create a tourism and business environment that always prioritizes sustainability for the surrounding environment (S2, S3, O2, O5)</p>	<p>(WO1) Conducting studies, strategic plans, and optimal periodic monitoring of protected key biota by creating a reference database for protected biota inventory and sustainable tourism management as prevention of the extinction of protected biota (W1, W4, W5, O2, O4, O5)</p> <p>(WO2) Optimizing cooperation between managers, government, and NGOs to raise awareness of environmental sustainability to create sustainable tourism with sustainable human resources from the community and tourists (W2, O1, O2, O5)</p> <p>(WO3) Reviewing and continuously monitoring the establishment of erosion and accretion control structures so that they can always provide benefits for sustainable coastal ecology (W3, O2, O3, O5)</p>
Threat (T1, T2, T3, T4, T5)	<p>(ST1) Establishing cooperation with managers, government, and NGOs to conduct studies on the threat of climate change to coastal ecosystems (seagrass, mangrove, coral) as well as optimal management strategies as an effort to prevent the threat of climate change (S1, S2, T1, T3)</p> <p>(ST2) Review, tighten permits, and supervise the use of coastal management land and create an optimal approach strategy so that conflicts of interest and development of certain areas that pay less attention to environmental aspects and protected animal habitats can be reduced (S1, S3, S5, T2, T3, T4, T5)</p> <p>(ST3) Conducting education and monitoring in a measured and comprehensive manner in coastal communities regarding the importance of economic down streaming and sustainable management of natural resources and fisheries to create a parallel economic and ecological ecosystem so that the community and the environment feel the positive impacts of each other (S2, S3, T1, T2, T3, T4, T5)</p>	<p>(WT1) Conducting studies on natural threats such as climate change, erosion, and accretion as an effort to prevent and reduce the negative impacts of these threats (W2, W3, T1)</p> <p>(WT2) Optimizing supervision and strengthening law enforcement related to activities that can have a negative impact or threaten the potential of natural resources and fisheries as well as protected habitats and biota within them (W1, W4, W5, T2, T3, T5)</p>

Table 8. Alternative strategies based on SWOT matrix strategy combinations

SWOT combination	Factor relevance	Total score	Priority rank
SO strategy			
SO1	S1, S2, O1, O2, O4, O5	2.556	2
SO2	S1, S2, S3, S5, O1, O4, O5	2.833	1
SO3	S1, S2, O3, O5	1.600	8
SO4	S1, S2, S3, S5, O5	1.969	4
SO5	S2, S4, S5, O1, O2, O5	2.336	3
SO6	S2, S3, O2, O5	1.575	9
WO strategy			
WO1	W1, W4, W5, O2, O4, O5	1.813	6
WO2	W2, O1, O2, O5	1.488	10
WO3	W3, O2, O3, O5	1.259	11
ST strategy			
ST1	S1, S2, T1, T3	1.226	12
ST2	S1, S3, S5, T2, T3, T4, T5	1.835	5
ST3	S2, S3, T1, T2, T3, T4, T5	1.613	7
WT strategy			
WT1	W2, W3, T1	0.479	14
WT2	W1, W4, W5, T2, T3, T5	1.199	13

Based on the calculations above, 3 main priorities were taken in determining coastal management strategies in biodiversity conservation efforts to maintain the sustainability of ecosystem conditions and support the lives of protected rare organisms. The priority falls on the combination of SO2, i.e., creating a strategy for controlling activities in coastal areas, so that utilization always pays attention to economic and ecological aspects that are equitable. Sustainable utilization must pay attention to various aspects, not only aspects of economic benefits, but also ecological or environmental aspects. This is in line with the statement of Suryanti et al. (2019), which explains that coastal management is a process of managing coastal natural resources and environmental services that integrates government activities, the business world and society, horizontal and vertical planning, terrestrial and marine ecosystems, and science and management to improve community welfare.

The role of the government, i.e., the Karimunjawa National Park as a stakeholder and authority in the Karimunjawa National Park area, as well as the role of non-governmental organizations such as the World Conservation Society, which functions as an indirect supervisor and community motivator, should be able to become the main driver in managing mangrove areas as conservation and economic areas. In line with the statement of Suasa et al. (2024), the presence of NGOs themselves can have a significant impact on public values, especially in environmental management, through various actions, such as encouraging community participation, holding campaigns, and being directly involved in helping the government.

The second priority falls on the combination of SO1, which is optimizing social media branding in promoting the

natural beauty and conservation activities between coastal ecosystems (mangrove, seagrass, and coral) for tourist education and as an effort to create sustainable tourism. Education and socialization to the community and tourists are very necessary because of the lack of public awareness about how to enjoy nature without polluting it. In line with Baloch et al. (2023), who stated that it is necessary to provide education to tourists and the surrounding community about environmental sensitivity and concern, because tourism without good management can endanger the ecosystem and culture of the surrounding community and cause significant ecological damage. The development of increasingly sophisticated technology opens up opportunities to introduce the natural beauty of Karimunjawa National Park widely. This is supported by Kotler and Armstrong statement (2018), which states that each location can be branded by creating and communicating an identity for the location in question. In this case, branding efforts through social media in promoting the natural beauty and conservation activities between coastal ecosystems can be done by creating a positive image of the condition of mangroves, seagrass, and coral reefs, which are the main attractions in Karimunjawa National Park.

The third priority that can be done is in the combination of SO5 by optimizing mobility facilities and access, as well as tightening supervision in the management of mobilization to industrial waste, so that the environmental capacity and tolerance to waste are always maintained. This is in accordance with the statement of Aspianny et al. (2019), that most of the problems related to the degradation of natural resources due to human activities exceed the environmental carrying capacity. Most people do not pay much attention to this problem, although some people are starting to realize it and, with a little knowledge, are trying to overcome the problem. Research from Puryono and Suryanti (2019) stated that as many as 61.65% of respondents agreed that the development of ponds was a factor causing mangrove degradation, besides other causes of mangrove degradation were fisheries cultivation activities by 51.13%, and the construction of fisheries cultivation facilities by 48.87%. Therefore, supervision regarding the management of mobilization to industrial waste is very necessary, especially in national park areas.

In addition to human factors, the condition of the ecosystem in Karimunjawa National Park is crucial for the health of the habitat and biodiversity, particularly in vital ecosystems such as mangroves, seagrass beds, and coral reefs. Some biotas, especially endangered or protected species, are sensitive to changes in water conditions. Therefore, poor ecosystem conditions impact the diversity of biota. The conclusions drawn from this study are that the diversity index (H') is classified as moderate, the evenness index (e) is classified as stable, and the dominance index (C) has low dominant species. The coastal management strategies prioritized for implementation in Karimunjawa National Park are in quadrant 1. These strategies that utilize the strengths of existing areas and maximize the opportunities they have, which includes coastal activity

control, branding, and optimization of facilities and supervision.

The recommendation that can be given is that further research should focus on monitoring the condition of ecosystems and biota on the islands outside Karimunjawa National Park. Practical policies are needed to implement zoning and integrated coastal activity monitoring in Karimunjawa National Park. The capacity of communities and stakeholders in conservation and environmental monitoring needs to be strengthened through training and technology.

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