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Level of Suitability of Marine Ecotourism Zones for Snorkeling and Diving Activities in the Kangean Islands, East Java, Indonesia

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A B S T R A C T

The tourism sector has an important role in increasing state revenue and economic growth of the community, especially coastal communities. One of the mainstays of Indonesian tourism is marine tourism, considering that Indonesia is an archipelago with the second longest coastline in the world. The Kangean Islands are islands that have not been maximally utilized, especially for the utilization of marine tourism areas. The charm of underwater natural beauty in the form of coral reef ecosystems is a tourism potential worth developing. The purpose of this research is to analyze the coral reef ecosystem's condition and the level of marine ecotourism suitability for snorkeling and diving activities in the waters of the Kangean islands. The object and material of this research are coral reef ecosystems in the Kangean Islands region and spatial data derived from Sentinel 2A satellite imagery. This research used a purposive sampling method to determine 12 sampling points spread over three observation stations: Sadulang Besar Island, Sadulang Kecil Island, and Sitabok Island. The results of the calculation of the TSI value of snorkeling activities, namely at point 1, the TSI value is 1.795, point 2 is 2.425, points 3 and 4 are 0.51, point 5 is 1.655, point 6 is 2.27, point 7 is 2.685, point 8 is 1.45, point 9 is 1.795, point 10 is 2.17, point 11 is 1.095, point 12 is 2.1. The results of the calculation of the diving TSI value are at point 1, the TSI value is 1.845, point 2 is 2.325, points 3 and 4 are 0.66, observation point 5 is 1.425, point 6 is 1.85, point 7 is 2.645, point 8 is 1.17, observation point 9 is 1.845, point 10 is 1.85, point 11 is 0.845, point 12 is 1.85. This research concludes that the condition of coral reef ecosystems in the Kangean Islands is quite good. The distribution of coral reef ecosystems in the research location is the reef barrier or barrier where coral reefs can grow and live well in shallow waters bordering deep waters or adjacent to the shore. Based on the calculation of spatial scoring and TSI values, observation point 7 is recommended as a core zone, observation point 2 as a diving ecotourism zone, and observation points 6, 10, and 12 as snorkeling ecotourism zones.

Keywords: marine ecotourism, Tourism Suitability Index, Kangean islands, coral reefs.

1. Introduction

Indonesian tourism has an important role as one of the sources of foreign exchange earnings and can encourage national economic growth. Tourism has also contributed to the development of the world economy and has mobilized nearly 700 million people worldwide. Tourism is expected to continue growing as people become increasingly mobile and prosperous today. (Yakup dan Haryanto, 2019). In addition to contributing to the economic aspect, tourism should also be based on the principle of natural sustainability, such as not damaging and polluting the marine ecosystem. Several factors can influence the development of marine tourism, including tourist attraction, availability of facilities and infrastructure to support tourism activities, local community participation, the existence and role of tourism institutions, investment opportunities, environmental quality, resource protection, government policies, and marketing. (Ikhlas *et al*., 2023).

As the world's largest archipelago, Indonesia has a wealth of natural resources with great potential. Indonesia's coral reefs contribute as much as 21% of the world's coral reef wealth, and 75% of the world's coral species can be found in Indonesia. One of the marine environmental services that is very prospective to support the national economy is the development of marine tourism. On a national scale, economic growth derived from marine tourism positively impacts the country's balance sheet, both in terms of domestic and national income or Gross National Product (GNP). (Yustinaningrum, 2017). Coral reefs are Indonesia's most threatened marine resources (Kunzmann dan Efendi, 1994). Coral reefs are very sensitive to changes in the surrounding environment, both by natural factors and human activities. Based on this, appropriate management policies need to be implemented to maintain the survival of coral reef ecosystems, which will further increase the productivity of the waters. (Jaelani *et al*., 2015).

The Kangean Islands are a group of islands that make up the easternmost part of Madura Island. The archipelago consists of 60 islands with an area of 487 km². The largest islands are Kangean (188 km²), Paliat Island, and Sepanjang Islands, and are divided into three districts, namely the Arjasa sub-district, Sapeken sub-district, and Raas sub-district. The potential beauty of the Kangean Islands is a special attraction that can be used as a marine tourism object, so this island is projected to be one of the mainstays of the tourist area in Sumenep Regency, Madura, East Java. (Rini *et al*., 2015).

Kangean Island in Sumenep Regency is one area with marine tourism potential that has not been well processed, geographically located between 6.50 ° N - 115.25 ° E. The islands in Sumenep have no modern industrial activities because of their relatively distant location. Surabaya-Sumenep road is about 200 km, and sea travel time from Sumenep to Kangean Island is about four hours. Kangean has enormous tourism potential, namely a marine park with a beautiful coral reef ecosystem, but is threatened with damage due to human activity. Human activities to fulfill economic needs are the main cause of coral reef damage. If the problem of people's economic limitations can be overcome, fishing efforts that are not environmentally friendly should be controlled. One of the efforts taken is to utilize the natural resources themselves, especially coral reefs, to support the economy of the island community (Rini *et al*., 2015). Ecotourism is one of the right activities for developing marine tourism while supporting the conservation of coral reef ecosystems on Kangean Island. (Arisandi *et al*., 2018).

Based on the explanation above, research is necessary to determine the condition and suitability of the coral reef ecosystem for marine ecotourism activities. This study aims to analyze the condition of the coral reef ecosystem and the suitability of marine ecotourism for snorkeling and diving activities in the waters of the Kangean islands.

2. Literature Review

2.1 Coral Reef Ecosystem

A coral reef is an ecosystem symbiotic with a group of animals belonging to the phylum Cnidaria that can produce an exoskeleton of calcium carbonate. Corals can be colonized or solitary, but almost all hermatypic corals are colonies with various individual coral animals or polyps occupying small bowls or colarites within a massive skeleton. Coral reefs are highly complex and productive ecosystems with a high diversity of biota, such as mollusks, crustaceans, and reef fishes. Biota living in coral reefs is a community unit that includes a collection of biota groups from various trophic levels, where each component in this coral reef community is closely dependent on each other. Coral reefs are a collection of coral animals (reef coral) that live at the bottom of the water and produce limestone CaCO3. Coral reefs get their food in two ways: by using their tentacles to catch plankton and through tiny algae (zooxanthellae) that live in coral tissue. Several types of zooxanthellae can live on a single coral, usually found in large numbers in each polyp, living symbiotically, providing color to the polyp, energy from photosynthesis, and 90% of the polyp's carbon needs. Zooxanthellae receive essential nutrients from corals, providing as much as 95% of their photosynthetic output (energy and nutrients) to corals (Supriharyono, 2007).

The process of coral reef formation takes a long time; during that time, coral reefs are inhabited by various living things. Thousands of tiny animals called polyps form the amazing architecture of coral reefs. In its simplest form, a coral may consist of a single polyp with a tube-like body with a mouth at the top and surrounded by tentacles. In many coral species, individual polyps develop into many individuals called colonies. Coral reefs are typical tropical ecosystems with distribution centers in the Indo-Pacific region. Temperature and water surface circulation factors control the limited distribution of coral reefs in tropical waters and latitudinally extending from southern Japan to northern Australia. Meanwhile, longitudinal distribution will be strongly influenced by connectivity in the form of stepping stones. The combination of physical environmental factors (temperature and surface circulation) with the large number of stepping stones in the Indo-Pacific region is a factor that strongly supports the extent of coral reef dispersal in the area. Now, almost 800 species of corals have been described. Of these corals, 600 species are found in Southeast Asia, especially in Indonesia and the Philippines (Burke et al. 2002). Considering the area of 34% (51% contribution of Indonesia's coral reef area) of the total area of coral reefs in the world, biogeographically, this region is declared as the center of origin of corals in the world (Veron, 1995).

Coral reefs are almost spread along the coast throughout Indonesia because they support the life of coral reefs, especially in coastal islands. Corals are the main development in the coral reef ecosystem. Coral reefs are important massive deposits of calcium carbonate (CaCO3) mainly produced by corals (Filum Cnidaria, Class Anthozoa, Order Madreporaria = Scleractinia) with little addition of calcareous algae and other organisms that secrete calcium carbonate (Nybakken,1992). Coral communities are limited to shallow waters, as symbiotic algae require sunlight for photosynthesis. The need for and adaptation to light in such corals to maintain maximum rates of calcification and photosynthesis can be kept to below 20 meters depth under clean water conditions (Nybakken,1992).

2.2 Marine Ecotourism

Marine ecotourism is a coastal and marine tourism activity developed with a marine conservation approach that utilizes the character of coastal and marine resources. Marine ecotourism management is a management concept that prioritizes sustainability and uses natural resources and community culture. The idea of ecotourism management is oriented towards sustainability and, more than that, maintaining the value of natural and human resources. To preserve these values, ecotourism companies do not exploit natural resources but only use natural and cultural services to meet visitors' physical, knowledge, and psychological needs. Ecotourism is not selling a place (destination) or area but selling a philosophy; this makes ecotourism have a sustainable value and will not recognize market saturation (Harahab et al., 2020).

Ecotourism focuses on three main things: the sustainability of nature or ecology, providing economic benefits, and being psychologically acceptable in the community's social life. So, ecotourism activities provide everyone with access to see, know, and enjoy local communities' natural, intellectual, and cultural experiences. Based on this definition, marine ecotourism can be defined as a form of tourism that utilizes marine waters and surrounding areas, being responsible for preserving the marine environment and local culture and providing economic benefits to coastal communities. Unlike ordinary natural tourism, marine ecotourism requires tourists to be “smart” towards nature, namely having an awareness/understanding of the preservation of coastal and marine nature. Marine ecotourism is provided for tourists who have a good sense of conservation. At the very least, tourists should have the

ability to swim so that their activities in the marine tourism zone do not step on corals as a place of rest. Tour guides should direct tourists to act wisely towards aquatic nature by equipping them with conservation knowledge before they do snorkeling or diving (Yuliana, 2017).

2.3 Suitability of Marine Tourism Area

Determination of the suitability class of the area for the use of marine ecotourism with the type of diving and snorkeling tourism activities by referring to the analysis of the tourism suitability index (Yulianda et al. 2010). The weighting of the suitability of water areas around the coast and small islands for snorkeling and diving tourism is carried out by considering the limiting factors of brightness, cover, type of live coral, reef fish diversity, depth, current speed, and width and area of coral beds. These limiting parameters were given weighting and scores. For weighting, all parameters are based on the level of importance for snorkeling and diving activities (Zulfikar *et al.*, 2011). According to Arifin (2008), the requirements as parameters needed for marine tourism activities, especially diving and snorkeling, include (1) percent coral cover, (2) water brightness, (3) types of life forms, (4) types of reef fish, (5) current speed, (6) depth of coral reefs. Coral reef areas with a brightness value of 80-100% are the most suitable locations for diving tourism. Coral reef areas with 20-50% brightness are still considered ideal for diving tourism. Coral reef areas with a brightness value of less than 20% are considered unsuitable.

3, Methods

The methods used in this research are survey and descriptive methods with the aim of exploring existing facts. According to Nazir (1999), the survey method is an investigation to obtain facts from existing symptoms and seek factual information. The research was conducted in the Kangean Islands region, Sumenep Regency, East Java Province, Indonesia. This research was conducted from March 2024 to April 2024. To determine the condition of coral reefs, direct sampling was carried out in typical coral reef habitats and 12 sampling points were determined in the three observation station areas with the following coordinates :

Table 1 – Coordinate the point of the observation location.

Sampling Point	Observation Station	Coordinates	
		South latitude	East Longitude
1	Sadulang Besar Island	06° 55' 47.09"	115° 47' 07.50"
2	Sadulang Besar Island	06° 58' 05.59"	115° 47' 29.35"
3	Sadulang Besar Island	06° 57' 55.37"	115° 47' 02.92"
4	Sadulang Besar Island	06° 56' 43.48"	115° 48' 01.42"
5	Sadulang Kecil Island	06° 59' 16.78"	115° 45' 17.54"
6	Sadulang Kecil Island	06° 58' 46.07"	115° 43' 50.47"
7	Sadulang Kecil Island	06° 57' 11.42"	115° 44' 33.68"
8	Sadulang Kecil Island	06° 58' 25.68"	115° 46' 04.06"
9	Sitabok Island	06° 58' 06.47"	115° 42' 38.85"
10	Sitabok Island	06° 58' 17.32"	115° 42' 20.52"
11	Sitabok Island	06° 57' 55.62"	115° 42' 15.17"
12	Sitabok Island	06° 57' 36.07"	115° 42' 23.27"

The suitability analysis conducted in this study is only focused on the designation of marine ecotourism areas that utilize coral reef ecosystems, in this case, the types of diving and snorkeling activities. Weighting is based on the level of importance of a parameter while scoring is based on the quality of each parameter. For parameter criteria in calculating the suitability index of snorkeling and diving tourism using the reference from Yulianda (2019) as follows :

Table 2 – Snorkeling Tourism Suitability Matrix.

Criteria	Range	Rate	Weight	Score
Water clarity (%)	<20	0	0.100	0
	20-<80	1		0.1
	80-<100	2		0.2

	100	3		0.3
Percentage of coral communities (%)	<25	0	0.375	0
	25-50	1		0.375
	>50-75	2		0.75
	>75	3		1.125
Coral life forms	<4	0	0.145	0
	4-7	1		0.145
	>7-12	2		0.29
	>12	3		0.435
Number of reef fish species	<10	0	0.140	0
	10-<15	1		0.14
	15-20	2		0.28
	>20	3		0.42
Current velocity (cm/sec)	>50	0	0.070	0
	>30-50	1		0.07
	>15-30	2		0.14
	0-15	3		0.21
Depth of Coral Reef(m)	>10, <2	0	0.100	0
	>6-10	1		0.1
	>4-6	2		0.2
	2-4	3		0.3
Coral bed width (m)	<20	0	0.070	0
	20-35	1		0.07
	>35-45	2		0.14
	>45	3		0.21
			1	

Table 3 – Diving Tourism Suitability Matrix.

Criteria	Range	Rate	Weight	Score
Water clarity (%)	<20	0	0.150	0
	20 - <50	1		0.15
	50 – 80	2		0.3
	>80	3		0.45
Percentage of coral communities (%)	<25	0	0.375	0
	25-50	1		0.375
	>50-75	2		0.75
	>75	3		1.125

Coral life forms	<4	0	0.135	0
	4-7	1		0.135
	>7-12	2		0.27
	>12	3		0.405
Number of reef fish species	<10	0	0.120	0
	10-<15	1		0.12
	20-15	2		0.24
	>20	3		0.36
Current velocity (cm/sec)	>50	0	0.070	0
	>30-50	1		0.07
	>15-30	2		0.14
	0-15	3		0.21
Depth of Coral Reef(m)	>30; <3	0	0.150	0
	>20-30	1		0.15
	>15-20; 3-<6	2		0.3
	6-15	3		0.45
			1	

Based on the suitability matrix table above, the total value between scores and weights is calculated and categorized into several classes. The division of marine ecotourism suitability classes refers to (Yulianda, 2019) divided into four suitability classes, namely: very suitable with TSI $\geqslant$ 2.5, suitable with a value of 2.0 $\leqslant$ TSI < 2.5, not suitable with a value of 1 $\leqslant$ TSI < 2.0; and very unsuitable with a value of TSI < 1. After comparing the class interval values, the suitability class is mapped using spatial analysis.

4. Result and Discussions

Utilization of the beauty of the coral reef ecosystem in marine ecotourism activities consists of 2 activities, namely snorkeling and diving. The calculation of the tourism suitability index (TSI) between snorkeling and diving activities based on Yulianda (2019) there are differences in several parameters, including the depth interval and width of the coral bed. The measurement results of several parameters used to calculate the suitability index of snorkeling and diving tourism are in the table below.

Table 4 – Measurement results of TSI parameters at station 1 Sadulang Besar Island

TSI Parameters	Sampling 1	Sampling 2	Sampling 3	Sampling 4
Coral Cover (%)	37,2 %	59,7 %	0%	0%
Water clarity (%)	96,67 %	76,67 %	100%	100%
Coral Depth (m)	3	3	1,1	1,5
Coral Life Form	11	13	0	0
Reef Fish Species	17	22	6	4
Current velocity (cm/sec)	6	10.7	7	10.3
Coral bed width (m)	41	50	0	0

Table 5 – Measurement results of TSI parameters at station 2 Sadulang Kecil Island

TSI Parameters	Sampling 5	Sampling 6	Sampling 7	Sampling 8
Coral Cover (%)	34,67 %	57,73 %	81,97 %	23,14 %
Water clarity (%)	85,7 %	100%	96,5%	100%

Coral Depth (m)	2,8	2,85	3,1	2,9
Coral Life Form	9	11	12	9
Reef Fish Species	11	20	25	16
Current velocity (cm/sec)	12.3	17.5	22.3	14.1
Coral bed width (m)	44	49	50	29

Table 6 – Measurement results of TSI parameters at station 3 Sitabok Island

TSI Parameters	Sampling 9	Sampling 10	Sampling 11	Sampling 12
Coral Cover (%)	28,15 %	56,87 %	24,53 %	68,13 %
Water clarity (%)	98,7 %	97,22 %	100%	97,27 %
Coral Depth (m)	3,85	2,16	2,3	2,57
Coral Life Form	10	11	7	10
Reef Fish Species	19	15	10	20
Current velocity (cm/sec)	14.7	21.9	16.9	18.4
Coral bed width (m)	37	49	33	44

Based on the calculations of several parameters in the table above, these parameter values were then input into the tourism suitability index formulation. Each parameter value has a score interval ranging from 0 to 3, and the converted scores were multiplied by the weight assigned to each parameter. The weight values are determined by each parameter's level of importance or attractiveness as a marine tourism object. The TSI (Tourism Suitability Index) calculations for snorkeling tourism at each observation point can be seen in the table below.

Table 7 – The Snorkeling Tourism Suitability Index (TSI) calculation results at Station 1 on Sadulang Besar Island.

TSI Parameters	Weight	Sampling 1		Sampling 2		Sampling 3		Sampling 4	
		Rate	Score	Rate	Score	Rate	Score	Rate	Score
Coral Cover	0.375	1	0.375	2	0.75	0	0	0	0
Water clarity	0.1	2	0.2	1	0.1	3	0.3	3	0.3
Coral Depth	0.1	3	0.3	3	0.3	0	0	0	0
Coral Life Form	0.145	2	0.29	3	0.435	0	0	0	0
Reef Fish Species	0.14	2	0.28	3	0.42	0	0	0	0
Current velocity	0.07	3	0.21	3	0.21	3	0.21	3	0.21
Coral bed width	0.07	2	0.14	3	0.21	0	0	0	0
total score	1		**1.795**		**2.425**		**0.51**		**0.51**

Table 8 – The Snorkeling Tourism Suitability Index (TSI) calculation results at Station 2 on Sadulang Kecil Island.

TSI Parameters	Weight	Sampling 5		Sampling 6		Sampling 7		Sampling 8	
		Rate	Score	Rate	Score	Rate	Score	Rate	Score
Coral Cover	0.375	1	0.375	2	0.75	3	1.125	0	0
Water clarity	0.1	2	0.2	3	0.3	2	0.2	3	0.3
Coral Depth	0.1	3	0.3	3	0.3	3	0.3	3	0.3
Coral Life Form	0.145	2	0.29	2	0.29	2	0.29	2	0.29
Reef Fish Species	0.14	1	0.14	2	0.28	3	0.42	2	0.28
Current velocity	0.07	3	0.21	2	0.14	2	0.14	3	0.21
Coral bed width	0.07	2	0.14	3	0.21	3	0.21	1	0.07

total score	1	**1.655**	**2.27**	**2.685**	**1.45**		

Table 9 – The Snorkeling Tourism Suitability Index (TSI) calculation results at Station 3 on Sitabok Island.

TSI Parameters	Weight	Sampling 9		Sampling 10		Sampling 11		Sampling 12	
		Rate	Score	Rate	Score	Rate	Score	Rate	Score
Coral Cover	0.375	1	0.375	2	0.75	0	0	2	0.75
Water clarity	0.1	2	0.2	2	0.2	3	0.3	2	0.2
Coral Depth	0.1	3	0.3	3	0.3	3	0.3	3	0.3
Coral Life Form	0.145	2	0.29	2	0.29	1	0.145	2	0.29
Reef Fish Species	0.14	2	0.28	2	0.28	1	0.14	2	0.28
Current velocity	0.07	3	0.21	2	0.14	2	0.14	2	0.14
Coral bed width	0.07	2	0.14	3	0.21	1	0.07	2	0.14
total score	1	**1.795**		**2.17**		**1.095**		**2.1**	

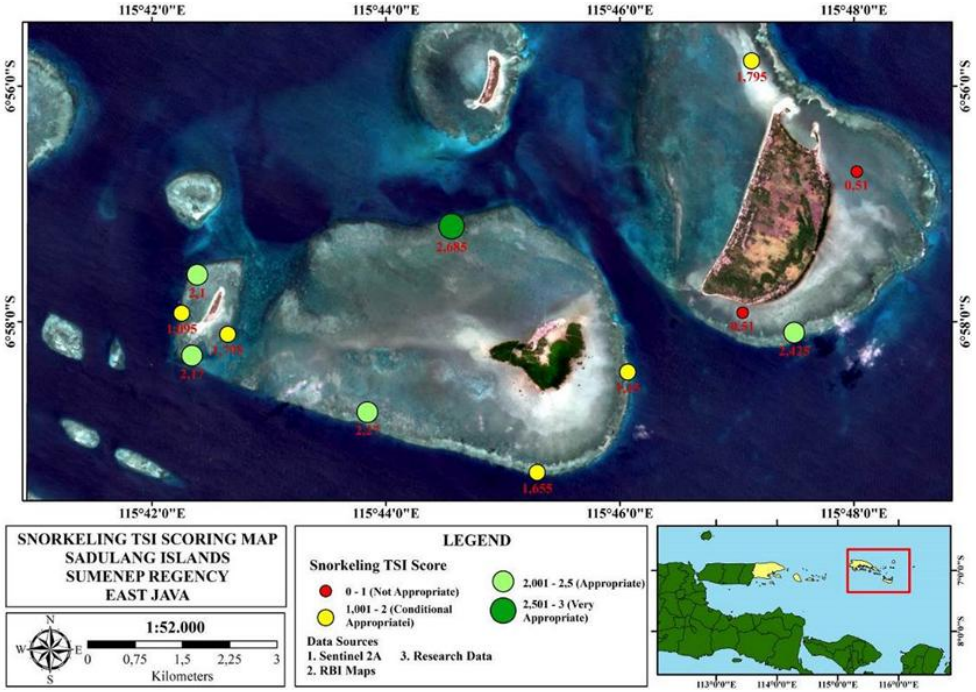
Based on these calculations, the TSI values are categorized into several suitability classes. According to Yulianda (2019), the highest suitability class is achieved when the TSI value is ≥ 2.5, classified as "highly suitable," while values of 2.0 ≤ TSI < 2.5 fall into the "suitable" category. If the TSI value is 1 ≤ TSI < 2.0, it is categorized as "unsuitable," and TSI values below one are considered "highly unsuitable." A summary of the TSI values for snorkeling about the suitability classes can be seen in the table below.

Table 10 – Recapitulation of Tourism Suitability Index (TSI) Score of Snorkeling Category.

Station	Sampling points	Snorkeling TSI Score	Category
Station 1	1	1.795	Conditional Appropriate
Sadulang Besar Island	2	2.425	Appropriate
	3	0.51	Not Appropriate
	4	0.51	Not Appropriate
Station 2	5	1.655	Conditional Appropriate
Sadulang Kecil Island	6	2.27	Appropriate
	7	2.685	Very Appropriate
	8	1.45	Conditional Appropriate
Station 3	9	1.795	Conditional Appropriate
Sitabok Island	10	2.17	Appropriate
	11	1.095	Conditional Appropriate
	12	2.1	Appropriate

After determining the suitability class categories for snorkeling tourism, the suitability values were plotted on a map using ArcGIS software, as shown in the figure below.

Fig. 1 - Map of Tourism Suitability Index scores for the snorkeling category.



The results of the TSI calculation for the diving tourism category at each observation point can be seen in the table below.

Table 11 – The calculation results of the Diving Tourism Suitability Index (TSI) at Station 1 on Sadulang Besar Island.

TSI Parameters	Weight	Sampling 1		Sampling 2		Sampling 3		Sampling 4	
		Rate	Score	Rate	Score	Rate	Score	Rate	Score
Coral Cover	0.375	1	0.375	2	0.75	0	0	0	0
Water clarity	0.15	3	0.45	2	0.3	3	0.45	3	0.45
Coral Depth	0.15	2	0.3	2	0.3	0	0	0	0
Coral Life Form	0.135	2	0.27	3	0.405	0	0	0	0
Reef Fish Species	0.12	2	0.24	3	0.36	0	0	0	0
Current velocity	0.07	3	0.21	3	0.21	3	0.21	3	0.21
Total Score	1		**1.845**		**2.325**		**0.66**		**0.66**

Table 12 – The calculation results of the Diving Tourism Suitability Index (TSI) at Station 2 on Sadulang Kecil Island.

TSI Parameters	Weight	Sampling 5		Sampling 6		Sampling 7		Sampling 8	
		Rate	Score	Rate	Score	Rate	Score	Rate	Score
Coral Cover	0.375	1	0.375	2	0.75	3	1.125	0	0
Water clarity	0.15	3	0.45	3	0.45	3	0.45	3	0.45
Coral Depth	0.15	0	0	0	0	2	0.3	0	0
Coral Life Form	0.135	2	0.27	2	0.27	2	0.27	2	0.27
Reef Fish Species	0.12	1	0.12	2	0.24	3	0.36	2	0.24
Current velocity	0.07	3	0.21	2	0.14	2	0.14	3	0.21
Total Score	1		**1.425**		**1.85**		**2.645**		**1.17**

Table 13 – The calculation results of the Diving Tourism Suitability Index (TSI) at Station 3 on Sitabok Island.

TSI Parameters	Weight	Sampling 9		Sampling 10		Sampling 11		Sampling 12	
		Rate	Score	Rate	Score	Rate	Score	Rate	Score
Coral Cover	0.375	1	0.375	2	0.75	0	0	2	0.75
Water clarity	0.15	3	0.45	3	0.45	3	0.45	3	0.45
Coral Depth	0.15	2	0.3	0	0	0	0	0	0
Coral Life Form	0.135	2	0.27	2	0.27	1	0.135	2	0.27
Reef Fish Species	0.12	2	0.24	2	0.24	1	0.12	2	0.24
Current velocity	0.07	3	0.21	2	0.14	2	0.14	2	0.14
Total Score	1		**1.845**		**1.85**		**0.845**		**1.85**

The TSI calculation results for the diving suitability category were grouped into four suitability classes based on Yulianda (2019). For the highest class, a TSI value of ≥ 2.5 indicates the "highly suitable" category, while a value of 2.0 ≤ TSI < 2.5 falls into the "suitable" category. A calculation result of 1 ≤ TSI < 2.0 is categorized as "unsuitable," and a TSI value of < 1 is classified as "highly unsuitable." A summary of the TSI values for diving suitability classes can be found in the table below.

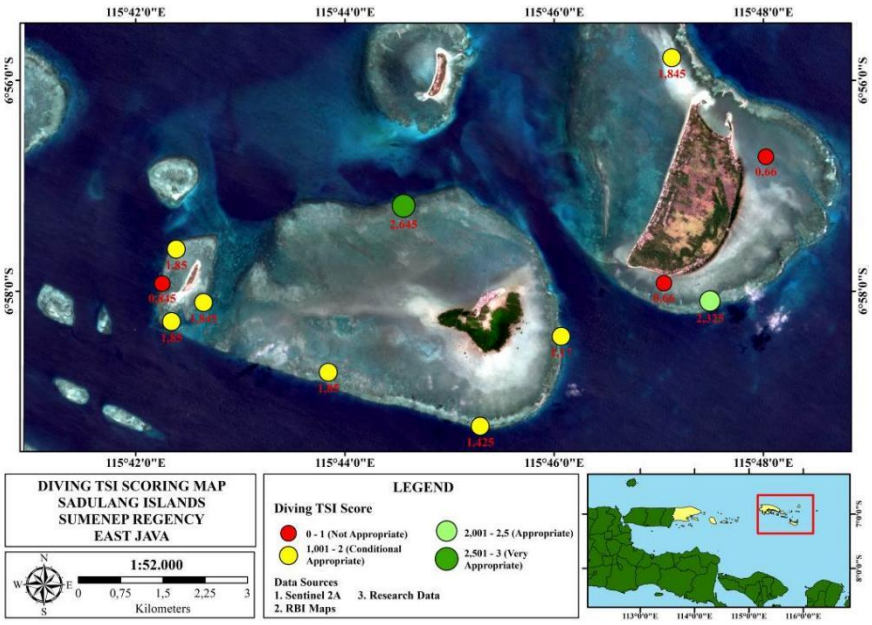
Table 14 – Recapitulation of Tourism Suitability Index (TSI) Score of Diving Category.

Station	Sampling points	Diving TSI Score	Category
Station 1	1	1.845	Conditional Appropriate
Sadulang Besar Island	2	2.325	Appropriate
	3	0.66	Not Appropriate
	4	0.66	Not Appropriate
Station 2	5	1.425	Conditional Appropriate
Sadulang Kecil Island	6	1.85	Conditional Appropriate
	7	2.645	Very Appropriate
	8	1.17	Conditional Appropriate
Station 3	9	1.845	Conditional Appropriate
Sitabok Island	10	1.85	Conditional Appropriate
	11	0.845	Not Appropriate

12	1.85	Conditional Appropriate

From the results of grouping the suitability class category of diving tourism, the value of the suitability class category is plotted on a map using ArcGIS software, as shown below.

Fig. 2 - Map of Tourism Suitability Index scores for the diving category.



Based on the concept of ecotourism, where activities or management of tourist areas must be based on the principle of environmental conservation to support the sustainability of the ecosystem, the management of tourist areas is divided into several utilization zones. According to Yulianda (2019), aquatic ecotourism zoning is divided into core, special, buffer, and utilization zones. Meanwhile, according to the Regional Regulation of East Java Province, Number 1 of 2018 concerning the Zoning Plan for Coastal Areas and Small Islands of East Java Province 2018-2038, Marine Protected Areas (MPAs) are divided into core zones and utilization zones, where the utilization zones are limited utilization zones and sustainable fisheries zones. So, from this reference, each area must be allocated as a core zone intended to protect animals and ecosystems; activities allowed in this zone are only special activities for research and education. Based on the TSI and spatial analysis scores, observation point 7 at station 2 of Sadulang Kecil Island is the core zone because the area has the highest coral reef density. As another consideration, the area is in the middle of the surrounding islands. The research locati**on'**s zoning division can be seen in the figure below.

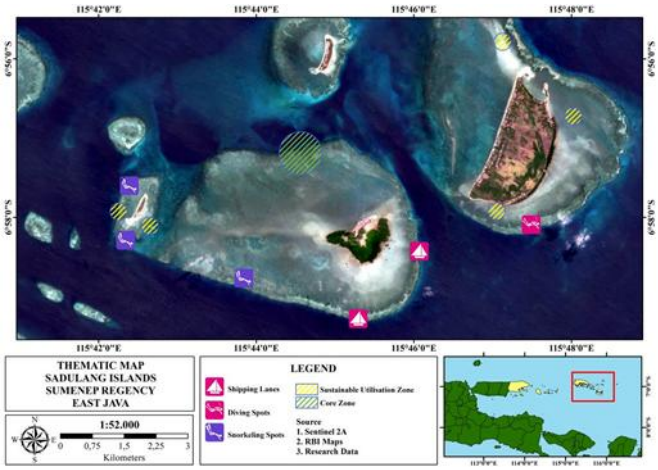


Fig. 3 - Peta Tematik Zona Kesesuaian Ekowisata Bahari.

Based on the picture above, point 2 at station 1 Sadulang Besar Island is suitable for use as a dive spot based on the results of the calculation of the TSI score. As another consideration, Sadulang Besar island is the main island with a Sadulang village office, so there is a dock. There is access to public transportation to and from Sapeken Island, the capital of Sapeken sub-district. Sapeken Island is the main port where the Pioneer Ship from Kalianget

Port, Sumenep Regency, is anchored. With these considerations, it will be more possible for Sadulang Besar island to be used as a base camp and a place to rest and store while preparing diving equipment. Observation points 1, 3, and 4 at station 1 of Sadulang Besar Island are sustainable fisheries zones.

North of station 2, Sadulang Kecil island, observation point 7, is a core zone based on the results of the TSI analysis. As another consideration, this area is in the middle of other islands. Observation points 5 and 8 at station 2 of Sadulang Kecil island are adjacent to the shipping channel from Sadulang Besar island to Sapeken island, a sub-district town. On the other hand, observation point 6 at station 2 of Sadulang Kecil island, based on TSI calculation analysis, is feasible for use as an ecotourism zone for snorkeling activities.

At station 3, Sitabok Island, by the analysis of TSI calculation, two observation points are suitable for use as ecotourism zones for snorkeling activities, namely observation point 10 and observation point 12. Meanwhile, for the balance of the ecosystem, observation point 9 and observation point 11 are designated as sustainable fisheries utilization zones. Sitabok Island not only has underwater beauty in the form of a fairly good coral reef ecosystem but also has its uniqueness, as it is the smallest island among the other islands. Sitabok Island has an area of approximately 1 square kilometer and is surrounded by beautiful white sand.

5. Conclusion

The condition of the coral reef ecosystem at the research site is quite varied at each observation point. Still, in general the condition of the coral reef ecosystem in the Kangean Islands is classified as good, based on the results of the calculation of the percentage of coral cover at each observation station both on Sadulang Besar island, Sadulang Kecil island and Sitabok island there is a percentage value of coral cover above 50%, at observation point 2 the percentage of coral cover is 59.7%, at observation point 6 is 57.73%, observation point 7 is 81.97%, observation point 10 is 56.87% and observation point 12 is 68.13%. Based on the average coral diversity index at the observation point, it has a value of 1.437, categorized as moderate diversity. As for the form of coral growth at the observation point, there are 7 to 13 types of life forms. The distribution of coral reef ecosystems on the three islands of the observation station has almost the same characteristics, with coral reef ecosystems growing and living well in shallow waters bordering deep waters or adjacent to the shore. The area adjacent to the shoreline is dominated by seagrass beds with sand substrate, except for the coastline in the western part of Sadulang Besar island, which is a shipping channel, so it is not limited by shallow water.

The Tourism Suitability Index (TSI) for snorkeling activities at Station 1 on Sadulang Besar Island shows that one observation point falls under the "suitable" category, with a TSI value 2.325 at observation point 2. At Station 2 on Sadulang Kecil Island, there are two observation points in the "suitable" and "highly suitable" categories. Specifically, observation points 6 and 7, with TSI values of 2.27 and 2.685, respectively. At Station 3 on Sitabok Island, two observation points are categorized as suitable, namely observation points 10 and 12, with TSI values of 2.17 and 2.1. For diving activities, Station 1 has one observation point that falls into the "suitable" category, specifically point 2, with a TSI value 2.325. At Station 2 on Sadulang Kecil Island, one observation point is categorized as "highly suitable," at observation point 7, with a TSI value of 2.645. At Station 3 on Sitabok Island, no observation points are suitable for diving tourism.

Based on spatial analysis, scoring, and TSI values, recommendations for utilization zones are as follows: Station 1 on Sadulang Besar Island should designate observation points 1, 3, and 4 as sustainable fishing zones, while point 2 should be defined as an ecotourism zone for diving activities. At Station 2 on Sadulang Kecil Island, observation points 5 and 8 should serve as navigation routes, point 7 should be a core zone for coral reef ecosystem preservation and sustainability, and point 6 should be designated an ecotourism zone for snorkeling activities. At Station 3 on Sitabok Island, observation points 9 and 11 should be utilized for sustainable fishing, while points 10 and 12 should be designated as marine ecotourism zones for snorkeling activities.

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References

Arisandi, A., B. Taman and A. Fauzan. 2018. Coral Reef Profile of Kangean Island, Sumenep District, Indonesia. *Scientific Journal of Fisheries and Marine* 10 (2): 76-83.

Arifin, T. 2008. Akuntabilitas dan Keberlanjutan Pengelolaan Terumbu Karang di Selat Lembeh, Kota Bitung. (Dissertation) Postgraduate Program IPB. Bogor

Burke, L., E. Selig and M. Spalding. 2002. Reef at risk in South East Asia. www.wri.org/reefatrisk.

Harahap, N. H. Riniwati dan C.A. Zulfaidah. 2020. Analisis Partisipasi Masyarakat Dalam Pengelolaan Ekowisata Clungup Mangrove Conservation (CMC). *Journal of Fisheries and Marine Research IV* (2): 296-307

Ikhlas, B., M. Uzra, & F. Firdaus. (2023). Peran Wisata Bahari Sebagai Ekoturisem Berkelanjutan Terhadap Ekonomi Nelayan. *Jurnal Teknik, Komputer, Agroteknologi Dan Sains*, 1(2), 217–225. https://doi.org/10.56248/marostek.v1i2.36

Jaelani, M L., N. Laili, Y. Marini. 2015. The Effect of Lyzenga's Algorithm on Coral Reef Mapping Using Worldview-2, A Case Study: Coastal Waters Of Paiton Probolinggo. www.brockmann-consult.de/cms/web/.

Kunzmann, A. dan Y. Efendi. 1994. Kerusakan Terumbu Karang Di Perairan Sepanjang Pantai Sumatera Barat*, Jurnal Pen. Perikanan Laut*, (91), 48–56.

Nazir, M., 1999. Metode Penelitian. Ghalia Indonesia. Jakarta.

Nybakken, J.W. 1992. Biologi Laut Suatu Pendekatan Ekologis. PT. Gramedia Pustaka Utama. Jakarta.

Rini, D. A. S., W. A. Praktiko and K. Sambodo. 2015. Identifying the Potential of Kangean Island Resource Area in Sumenep Regency Madura as a Marine Tourism Area. *Marine Journal*, 8 (2): 60-70.

Supriharyono. 2007. Coral Reef Ecosystem Management. Djambatan. Jakarta. 118 pp.

Suharsono. 2008. Jenis-jenis Terumbu Karang di Indonesia. Oceanography Central Research-LIPI, Jakarta, Indonesia. 344 pp.

Veron, J. E. N. 1995. Coral in space and time. Australian Institute of Marine Science Cape Ferguson, Townsville, Queensland.

Yakup, A. P. dan T. Haryanto. 2019. Pengaruh Pariwisata Terhadap Pertumbuhan Ekonomi Di Indonesia (Vol. 23, Issue 2).

Yuliana, E. 2017. Pengelolaan Ekowisata Bahari di Kawasan Konservasi Perairan Taman Nasional Karimunjawa. Optimalisasi Peran Sains & Teknologi Untuk Mewujudkan Smart City. Universitas Terbuka. 393 halm.

Yulianda, F., A. Fahrudin, A. A. Hutabarat, S. Harteti, Kusharjani, dan H.S. Kang. 2010. Pengelolaan Pesisir dan Laut Secara Terpadu (Integrated Coastal and Marine Management). Bogor (ID): Pusdiklat Kehutanan- Departemen Kehutanan Ri, Secem– Korea International Cooperation Agency.

Yulianda, F. 2019. Ekowisata Perairan : Suatu Konsep Kesesuaian dan Daya Dukung Wisata Bahari dan Wisata Air Tawar. Cetakan I, Penerbit IPB Press, Bogor. 5-83 halm.

Yustinaningrum, D. 2017. Pengembangan Wisata Bahari di Taman Wisata Perairan Pulau Pieh Dan Laut Sekitarnya Marine Tourism Development In Park Tourism Islands Of Pieh And Sea Surrounding.

Zulfikar, Y. Wardianto, dan I. Setyobudiandi. 2011. Kesesuaian dan Daya Dukung Ekosistem Terumbu Karang sebagai Kawasan Wisata Selam dan *Snorkeling* di Tuapejat Kabupaten Kepulauan Mentawai. *Jurnal Ilmu-ilmu Perairan dan Perikanan Indonesia*, 17(1) : 195-203.