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POTENTIAL OF CORAL REEF ECOSYSTEMS FOR DEVELOPING MARINE TOURISM ON PASIR PUTIH BEACH, SUKABUMI DISTRICT

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ABSTRACT

The coral reef ecosystem is one of the main ecosystems in coastal areas. Physically, it has a role as a protector of the coast from currents and waves, and ecologically, it has a role as a habitat for various marine biota for shelter and foraging. Besides that, with their elegance and beauty, coral reefs can become an attraction for marine tourism. This research aims to describe the condition of the coral reef ecosystem and analyze the suitability of coral reef conditions to determine the potential for marine tourism on Pasir Putih Beach, Sukabumi Regency. The method used is direct observation and measurement of parameters needed to determine the potential for marine tourism. Data processing and analysis were performed using CPCe 4.1 software and Microsoft Excel. The observations and data analysis results show that the potential for marine tourism in Pasir Putih Geopark Ciletuh can be considered reasonable according to the tourism suitability index criteria.

Keywords: Potential, Coral Reef Ecosystem, Marine Tourism

1. INTRODUCTION

Coral reefs are among the world's richest and most diverse coastal ecosystems. According to estimates, around one million species live in this ecosystem globally. Coral is an invertebrate animal belonging to the phylum Coelenterata or Cnidaria. These elements form the basis of the coral reef ecosystem, with their shape and structure providing habitat for various other species. The uniqueness of the coral reef ecosystem lies in its fertility, diversity of biota, and high aesthetic value. However, this ecosystem is also very vulnerable to environmental change. Factors such as increasing sea temperatures, pollution, and changes in water chemistry can harm coral reef ecosystems[1].

The main functions of coral reefs in marine ecosystems include providing habitat and shelter for various species, food sources and breeding grounds for the biota around them. In an economic context, coral reefs are also an important biological resource that produces several valuable products such as coral fish, algae, sea cucumbers and pearl shells[2].

Ecotourism is sustainable nature-based tourism that focuses on experience and education about nature, managed using a certain management system to provide the lowest negative environmental impact. It is not consumptive in nature and is locally oriented (in terms of control benefits that can be taken from business activities. Ecotourism is a tourism activity that is unique in nature. In this case, only activities that contain "eco" elements can be included in ecotourism, namely paying attention to ecological and economic aspects and community perception. In particular, experts say this ecotourism activity involves educational elements[3].

Marine tourism is a special interest tourism with activities related to maritime affairs, both above sea level (marine) and on the sea surface (submarine). Marine tourism is based on scenery, natural uniqueness,

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ecosystem characteristics, and the unique arts and culture of the coast and ocean. The concept and definition of marine tourism are divided into two parts, namely coastal tourism and marine tourism. Coastal tourism is related to leisure and recreation activities in coastal and offshore areas. In contrast, marine tourism is related to beach tourism but is more directed towards deep sea waters[4].

Ciletuh Bay, as an inseparable part of the Ciletuh-Palabuhanratu Geopark, has developed into a popular marine tourism destination, with the number of tourist visits increasing significantly yearly. In 2019, the number of visits reached 873,894 people, an increase of 154.11% compared to last year. This rapid tourism growth, although it has a positive impact on the local economy, also has the potential to harm the sustainability of the local ecosystem, especially coral reefs, which are the main attractions of this area. Therefore, assessing the land suitability and carrying capacity of coastal ecotourism in Ciletuh Bay is crucial, focusing on the coral reef area[5].

Ciletuh Bay coral reefs are part of Indonesia's rich coral reef biodiversity, with 590 species belonging to 80 coral genera[6]. These coral reefs are essential for marine life and contribute significantly to the tourism industry, national economy, and job creation. However, data on coral reefs in Ciletuh Bay is still minimal and has not been correctly exposed. The lack of data on diversity and spatial data for coral reefs in this area causes this. With the high level of tourism in Ciletuh Bay and the lack of primary coral reef data, there is a risk of the coral reef ecosystem degradation due to inappropriate management of coastal areas[7].

This research aims to determine the suitability of coral reef ecosystems as a base for marine tourism on Ciletuh Beach, Sukabumi Regency and to determine the factors that influence marine tourism development. This research will focus on the biophysical conditions of the coral reef ecosystem in Ciletuh Bay and strategies for developing sustainable coastal ecotourism.

2. RESEARCH METHOD

Time and Place

The research was conducted in March – May 2022. The research location was Pasir Putih Beach, in the Ciletuh Geopark area, Sukabumi Regency. This location was chosen because it is one of the famous marine tourism areas in West Java, known for its natural beauty and diverse coral reef ecosystem. Observations were made at the west and east of Pasir Putih beach. These two locations were chosen because they show various habitats and environmental conditions. They are expected to provide a more complete and holistic picture of the coral reef ecosystem and its influence on marine tourism potential.

Data Collection

The data collected includes physical and biological data on coral reef ecosystems, marine tourism activities, and socio-economic data on the surrounding community. Data was collected using various methods, including direct measurements in the field, surveys and interviews with respondents, visual observation and documentation. Two main methods were used to collect data: the Underwater Photo Transect method and the Belt Transect method. These two methods have their respective advantages and disadvantages and were chosen based on time efficiency, cost and accuracy of the data obtained.

Underwater Photo Transect Method

The underwater photo transect method UPT (Underwater Photo Transect) collects data using a digital camera or computer software technology in the field in the form of underwater photos taken by shooting using a camera equipped with a waterproof protector[8].

Belt Transect Method

The belt transect method describes the condition of coral reefs, starting from population, size, presence of ornamental corals, coral diameter, and types of coral in

a population. This method is reasonably easy to do. Another method that can be used is the development of the belt transect method, which is the video belt transect or video belt transect. This method uses video where data is collected along the transect and then repeatedly played to calculate data on the presence of coral, fish, and so on[9].

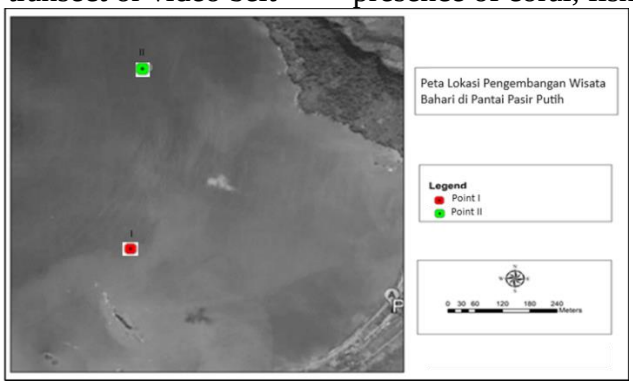

Figure 1. Research location

Data analysis

Data processing and analysis were carried out using the CPCe 4.1 application. Kohler & Gill[10] developed coral Point Count with Excel Extension (CPCe). This technique determines the number of random points used to analyze the photo. The number of random points used was 30 for each frame, representing estimating the percentage cover of categories and substrates. Based on the photo analysis process carried out on each photo frame, the category coverage percentage value for each frame can be obtained and calculated based on the following formula:

$$\text{Category cover percentage} = \frac{\text{Number of category points}}{\text{Number of random points}} \times 100\ \%$$

The condition of coral reefs is determined based on the percentage of live coral cover. According to the Decree of the Minister of Environment and Forestry No. 4 of 2001 concerning criteria for coral reef damage, the condition of coral reefs is categorized into four criteria[6], as written in Table 1.

Table 1. Coral reef percentage criteria

Percentage of live coral cover	Condition of coral reefs
0-24,9	Bad
25-49,9	Currently
50-74,9	Good
>75	Very good

Water Quality Measurement

The growth of coral reefs depends on the quality of the waters where the ecosystem is located. In general, water quality is determined by several physical parameters in the water[11]. Several parameters significantly influence the growth of coral reefs, namely temperature, salinity and acidity level of seawater. These three parameters are vital for coral reefs, so measurements must be carried out. Quality measurements are carried out by measuring the physico-chemical parameters of water. Measurements were carried out three times in each transect of the observation location, and then the average of the three repetitions was taken. Measurement data is obtained through direct data measurements. Measurement of water physicochemical parameters includes measurements of brightness (m), temperature (^{0}C), salinity (ppt), and acidity (pH).

3. RESULT AND DISCUSSION

Water Quality

Water quality at a location plays a significant role in the sustainability and health of coral reef ecosystems. Factors such as water temperature, salinity and clarity affect the function and growth of coral reefs and the organisms that live in them[12]. The water quality parameters required for the development of marine biota, including on coral reefs, must meet the Water Quality

Standards for Marine Biota stipulated in the Ministerial Decree of the Minister of the Environment of the Republic of Indonesia No. 51 of 2004[13] written in Table 2.

In this research, water quality parameters were measured at the research location at the eastern part (point I) and the western part (point II), where Pasir Putih Beach is located. The water quality parameters measured are temperature, salinity, brightness, current speed and pH. The results of measuring water quality are shown in Table 3.

Table 2. Minister of Environment Decree No. 51 of 2004

No	Parameter	Standards[13]
1	Temperature	26-31 ^{o}C
2	Salinity	30-35 ppt
3	pH	7.5-8.4

Table 3. Results of water quality observations at point I and point II

Research sites	Current Velocity (m/s)	Salinity (ppt)	Brightness (%)	Temperature (^{o}C)	pH
Point I	0,1	31,6	100%	29	7,8
Point II	0,1	33,5	80%	30	7,9

The optimal water temperature for coral reef growth is usually between 26-31°C. Therefore, the water temperature at both observation points is within the ideal range for coral reef growth. Salinity is also within the range that coral reefs can tolerate, usually between 30-35 ppt. Water brightness indicates the extent to which light can penetrate the water. High brightness (100% at point I and 80% at point II) shows that sunlight can penetrate quite deeply into the water, which is vital for photosynthesis and provides food and color to coral reefs.

The low current speed (0.1 m/s at both points) means the coral reefs are not exposed to strong currents that could damage their structure. However, currents are also crucial for carrying nutrients and oxygen and helping in the reproduction process of coral reefs. The pH of the water at both points is in the neutral range (7.8 and 7.9), which is ideal for coral reef life. A too acidic or alkaline pH can damage coral reefs and other organisms[14].

Coral Reef Cover

Coral reef cover is an important indicator of the health of coral reef ecosystems. The high cover percentage indicates that the coral reefs in both locations are still alive and functioning well. However, the "moderate" criterion suggests that the coral reefs at the study site require careful management and protection to prevent further decline and promote coral reef recovery and growth[15].

Based on observations, coral reef cover in both research locations shows good conditions. At a point I (eastern part), there are 722 pieces with seven coral reef cover substrates at a depth of 4 m. The percentage of live coral reef cover at this location is 29%, according to the Decree of the Minister of the Environment in 2001[16] (Table 1), which is included in the medium criteria (Figure 2).

Meanwhile, at point II (western part), there are 894 pieces with a coral reef cover substrate of 7 pieces, coral reef cover at a depth of 6 m with a percentage of live coral reef cover at this location is 36%, this is also included in the medium criteria according to Decree of the Minister of the Environment in 2001[16] (Figure 3).

Lifeform Composition

The lifeform composition or growth form of coral reefs is crucial in determining the structure and function of coral reef ecosystems. In this study, the composition of lifeforms at both observation points showed variation and dominance by several types of coral reefs[17].

At a point I (eastern part), the observation results show five types of coral reefs. The most dominant type of coral reef

is coral encrusting, which covers 13.68% of the total lifeforms. Encrusting coral is a coral reef that grows attached to the substrate and often covers the surface of rocks or another coral framework (Figure 4).

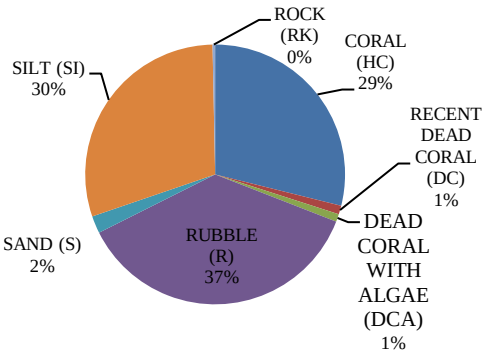

Figure 2. The coral cover graph at point I

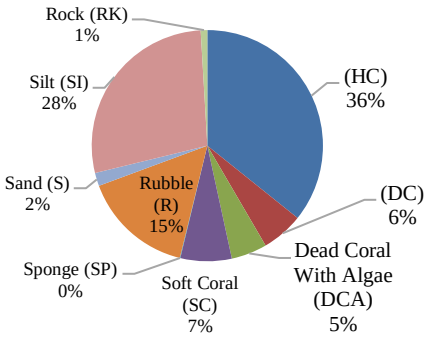

Figure 3. Coral cover graph at point II

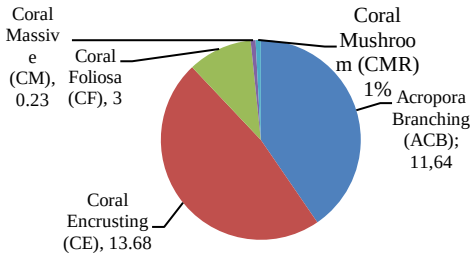

Figure 4. Lifefrom graph at point I

Meanwhile, at point II (western part), observation results show nine types of coral reefs. Acropora sub-massive is the most dominant coral reef, covering 40% of the total lifeforms. Sub-massive acropora is a type of coral reef with a larger and more complex shape, with structures such as trees or niches that offer habitat for various marine organisms (Figure 5).

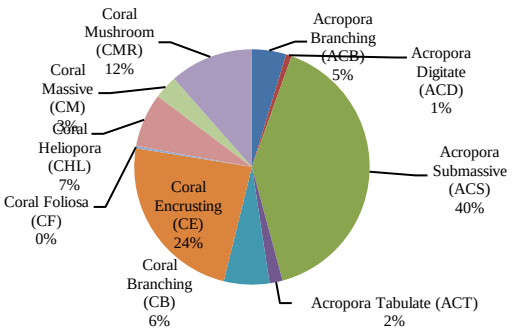

Figure 5. Life form graph at point II

This variation and dominance by several coral reefs shows that coral reefs in both locations have a relatively high diversity of growth forms. This diversity is vital for the health of coral reef ecosystems because different growth forms provide various types of habitat and food sources for other organisms in the ecosystem. However, dominance by several types of coral reefs can also indicate pressure or disturbance in the ecosystem, affecting the diversity and balance of coral reef species. Therefore, managing and protecting coral reefs in both locations must consider these factors.

Reef Fish

Coral fish play an essential role in coral reef ecosystems as primary consumers, predators, and as part of the food chain. In this study, the results of observations of coral fish showed variations in the number of species and families at both observation points[18].

At Point I, 86 species of coralfish belong to 6 families. Meanwhile, at Point II, 119 species of coral fish belong to 9 families. The higher number of species at Point II indicates a greater diversity of habitats and food sources at this location, supporting the presence of more reef fish species (Figure 6).

The most commonly found coralfish species is *Ctenochaetus striatus*, a member of the Acanthuridae family. This species is often found at Point II (the western part of Pasir Putih Beach). *C.striatus* is a species of coralfish that plays a vital role in coral reef ecosystems. These fish are algae eaters, which helps maintain the balance between

coral reefs and algae in the ecosystem. The results of these observations indicate that the coral reefs at both locations support the existence of various species of reef fish, indicating the health and productivity of the ecosystem. However, management and protection of coral fish and their habitats needs to be carried out to ensure the sustainability of this coral reef ecosystem.

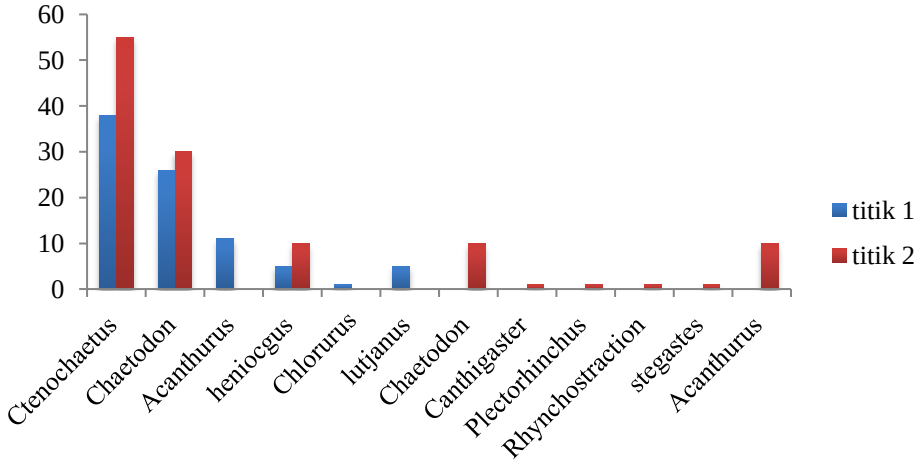

Figure 6. Coral fish graph

Potential Coral Reef Cover

Based on observations, coral reef coverage at Pasir Putih Beach, Ciletuh Geopark, ranges from 29 to 36%. The most significant percentage of live coral reef cover is in the western part of Pasir Putih Beach at a depth of 6 m with a rate of 36%, while the smallest percentage of live coral reef cover is in the eastern part at a depth of 4 m, namely 29%.

Based on the percentage value of coral reef cover, following the criteria for coral reef damage by Minister of Environment Decree No. 4 of 2001[16], the live coral reef cover obtained at Pasir Putih Beach is included in the medium criteria. This shows that coral reefs in this area require careful management and protection to remain sustainable.

To support marine tourism, the percentage of coral reef cover is vital in assessing suitability. According to Sari et al.[19], the standard marine tourism suitability matrix parameters for the marine tourism category assume that a higher level of coral community cover will provide better tourism value. In this context, the coral community cover parameter in the eastern and western parts of Pasir Putih Beach received a score of 1, indicating that the area is quite suitable for marine tourism activities.

Lifeform Potential of Coral Reefs

Variations in growth forms or lifeforms of coral reefs are essential in attracting visitors, especially divers and snorkelers. This variety of growth forms gives each coral reef ecosystem its beauty and uniqueness, making the tourist experience more exciting and memorable[20].

Based on observations, the two most dominant growth forms at Pasir Putih Beach, Ciletuh Geopark, are coral encrusting and ccropora submassive. Coral encrusting, as the name suggests, forms a hard layer that adheres to the substrate, often covering the surface of rocks or another coral framework. Meanwhile, submassive acropora has a larger and more complex shape, with tree-like structures or niches that offer habitat for other marine organisms.

This variety of growth forms is significant not only for tourism activities but also for the health of the coral reef ecosystem itself. Different growth forms provide habitats and food sources for other organisms in the ecosystem and influence ecological processes such as the carbonate cycle and energy flow[21].

In addition, research by Williams dan Polunin[22] shows that the percentage of live coral cover in a location can influence divers' interest in tourism activities. Therefore, increasing and maintaining the diversity of coral reef growth forms is important for developing sustainable tourism at Pasir Putih Beach, Ciletuh Geopark.

The Potential of Reef Fish

The diversity of coral fish species dramatically contributes to the attractiveness of marine tourism, especially for tourists who snorkel and scuba dive. According to Yulianda[23], The more diverse types of coral fish are found in a location, the more attractive the area is for tourism activities.

Based on observations, Pasir Putih Beach in the Ciletuh Geopark shows a relatively high diversity of coral fish species. At points I and II, various species of coral fish from multiple families were found, with the Acanthuridae family having the highest abundance. The Acanthuridae family, which includes species such as Ctenochaetus striatus, usually relies heavily on coral reefs as a habitat and food source. Their presence in large numbers may indicate that the coral reefs in this location are quite healthy and can provide sufficient food sources for this species.

Snorkelling Tourism Potential

Snorkelling is a popular marine tourism activity, but various parameters, including water brightness, coral community cover, type of coral growth, diversity of coral fish species, current speed, depth of coral reef and width of coral expanse, determine the suitability of a location for snorkelling. Based on these criteria, the two observation points in the Ciletuh Geopark have a relatively high level of suitability for snorkelling, with a suitability percentage of 66.6% at the first point and 78.3% at the second point.

According to British Sub-Aqua Club[24], the ideal water depth for snorkelling is between 3-5 m, with minimal wave conditions and exciting objects such as beautiful coral reefs. Areas with a depth of fewer than 3 m are usually not recommended for snorkelling activities due to the risk of damage to coral reefs by tourists, such as being stepped on or damaged by snorkelling equipment. Therefore, managing and maintaining a balance between tourism activities and environmental conservation is vital, especially in ecotourism.

Table 4. Results of marine tourism suitability - snorkelling category at Point I

Parameter	Criteria	Weight	Score	Total
Water brightness (%)	>80	30	3	90
Live coral cover (%)	25-50	20	1	20
Lifeform type	4-7	20	1	20
Types of coral fish	>50	10	2	20
Current speed	0-15	10	3	30
The depth of the waters	3-6	5	2	10
Wide flat stretch of coral	100-500	5	3	10

Table 5. Suitability results for marine tourism - snorkeling category at point II

Parameter	Criteria	Weight	Score	Total
Water brightness (%)	>80	30	3	90
Live coral cover (%)	25-50	20	1	20
Lifeform type	7-12	20	2	40
Types of coral fish	>50	10	3	30
Current speed	0-15	10	3	30
The depth of the waters	3-6	5	1	10
Wide flat stretch of coral	>500	5	3	15

Optimal snorkelling locations should ensure that tourists enjoy the underwater beauty while minimizing negative environmental impacts. This means it is essential to consider the depth and condition of coral reefs and ensure that tourists have the proper knowledge and equipment to avoid damaging coral reefs. Snorkelling activities that support marine tourism at the research location are determined by several parameters, as shown in Table 4 and Table 5.

Table 6. Suitability results for the marine-diving tourism category at Point I

Parameter	Criteria	Weight	Score	Total
Water brightness (%)	>80	30	3	90
Live coral cover (%)	25-50	20	1	20
Lifeform type	4-7	20	1	20
Types of coral fish	50-100	15	2	30
Current speed	0-15	10	3	30
The depth of the waters	6-15	5	3	15

Table 7. Suitability results for the marine–diving tourism category at Point II

Parameter	Criteria	Weight	Score	Total
Water brightness (%)	>80	30	3	90
Live coral cover (%)	25-50	20	1	20
Lifeform type	7-12	20	2	40
Types of coral fish	>100	15	3	45
Current speed	0-15	10	3	30
The depth of the waters	3-6	5	3	15

From the description above, with the support of good water quality at Pasir Putih Beach, the potential for coral reef cover and lifeforms, the potential for coral fish, the potential for snorkelling tourism, the potential for diving tourism, support for marine tourism activities in the area can be utilized. This follows research conducted by Satryanto regarding the factors that influence the development of marine tourism areas[25]. The results of observations and data analysis show that the potential for marine tourism at Pasir Putih Beach can be categorized as quite reasonable according to the criteria for the marine tourism suitability index; with this potential, the development of marine tourism at Pasir Putih Beach, Sukabumi Regency can be carried out.

4. CONCLUSION

The coral reef ecosystem at Pasir Putih Beach, Sukabumi Regency, shows significant potential as a basis for marine tourism development. Several factors support the development of marine tourism on Pasir Putih Beach, including good water quality, the potential for coral reef cover and lifeforms, the potential for coral fish, the potential for snorkelling tourism and the potential for diving tourism. The observations and data analysis results show that the potential for marine tourism at Pasir Putih Beach can be categorized as quite reasonable according to the criteria for the marine tourism suitability index. Marine tourism development at Pasir Putih Beach, Sukabumi Regency, can be carried out with this potential. Conservation measures such as planting coral reefs are needed to maximize tourism potential and ecological and environmental sustainability. Therefore, regular monitoring and appropriate management must be carried out to maintain the health of coral reef ecosystems. Local communities and government involvement is needed in managing coral reef ecosystems.

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