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TRANSFORMATION OF CORAL REEF ECOTOURISM THROUGH THE DEVELOPMENT OF SUPPORTING INFRASTRUCTURE AT BIG KELAGIAN ISLAND INDONESIA

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Abstract

Coral reefs play a crucial role as habitats where marine life can thrive and seek sustenance, as well as serving as attractive tourist destinations. The research aims to analyse the suitability of tourism and the carrying capacity of ecotourism on Kelagian Besar Island, Indonesia, along with its supporting infrastructure. The research method utilizes an analysis of tourism suitability and area carrying capacity for snorkelling and diving tourism, as well as observing the supporting infrastructure. The analysis resulted in an average suitability rating for snorkelling and diving tourism at 51.38% and 51.63%, respectively, across 7 stations, with a carrying capacity of 1395 and 3187 individuals per day for snorkelling and diving. Field observations revealed that the island's infrastructure is relatively adequate but still requires further improvement and development. To maximize the potential of the area, coral reef transplantation could be undertaken to enhance and maintain tourism suitability on the island. In conclusion, the overall tourism suitability analysis falls into the category of not suitable (S3), with a carrying capacity of 4,582 individuals per day for snorkelling and diving tourism, indicating the need for improving the quality of coral reefs and their supporting infrastructure for ecotourism management on the island.

***Keywords*:** Coral reefs, Diving, Snorkelling, Kelagian Besar Island, Supporting Infrastructure

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INTRODUCTION

Coral reefs are ecosystems that play a significant role in the underwater environment (Elise et al., 2019; Xu & Zhao, 2014; Hoegh-guldberg et al., 2017). Ecologically, coral reefs serve as habitats where fish can survive and feed (Berkström et al., 2012). Additionally, the underwater beauty with its diverse marine life such as anemones, algae, and fish around the coral reefs can be a stunning tourist attraction for activities like snorkelling and diving.

Snorkelling and diving tourism are among the most popular preferences for marine tourism in coral reef ecosystems (Shokri & Mohammadi, 2021; Lamb et al., 2014). Maximizing tourism empowerment can enhance the economic growth of the local community and support regional revenue (Xu et al., 2009). Therefore, good planning is necessary, one of which involves conducting an analysis of the Tourism Suitability Index (TSI) and the Area Carrying Capacity (ACC) (Romano et al., 2015). This analysis is useful to determine whether the area meets the criteria to be a suitable tourist destination.

The suitability value of tourism in an area can be assessed through spatial mapping obtained by analyzing satellite imagery data (Jokar et al., 2021). However, its accuracy may differ from actual field conditions. Without accurate planning and mapping, human activities such as tourism and coastal development will have a negative impact on coral reef ecosystems (Silveira et al., 2021). Therefore, data in the form of information on coral reef distribution and further research on Kelagian Besar Island are needed.

Perhaps research on the analysis of tourism suitability and area carrying capacity has been conducted on this island before, but this study incorporates variables that were not previously included, specifically regarding supporting infrastructure as an output. The aim of this research is to analyze the suitability of tourism and ecotourism carrying capacity on Pulau Kelagian Besar along with its supporting infrastructure. Therefore, this study is expected to yield new findings (novelty) and serve as a reference for ecotourism development on the island.

RESEARCH METHODOLOGY

Research Study

This research is a field study conducted on Kelagian Besar Island, specifically in the Padang Cermin District, Pesawaran Regency, Indonesia. The research was spread across 7 locations where data collection was carried out at each station [See Figure 1].

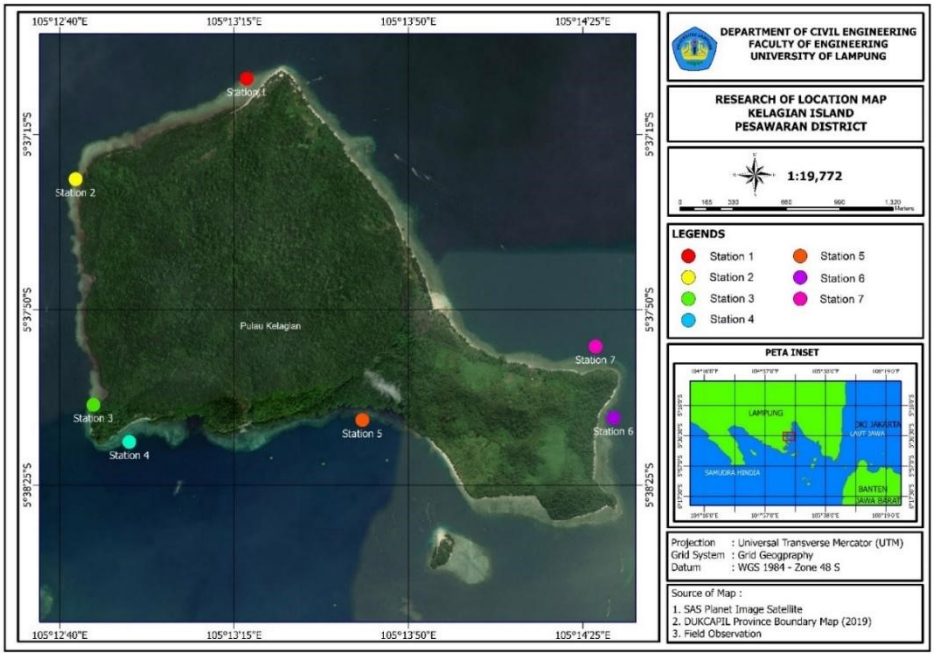

Figure 1: Research Location Map

Research Instruments

This research utilized a series of tools and materials, including:

a) An underwater camera for underwater photography.
b) A Garmin 64s GPS for accurate location recording.
c) A roll meter for distance measurement.
d) A Secchi disk to determine water clarity.
e) SCUBA diving equipment for diving.
f) Bottles and ropes for measuring current speed.

Tourism Suitability Data Collection Process

The analysis of the TSI diving category is based on 7 parameters, and the analysis of the TSI diving category is based on 6 parameters. The steps taken to obtain snorkelling and diving IKW data are as follows:

a) Water Clarity Data Collection: This is done using a device called a Secchi disk. The device is lowered into the sea, and observations are made to see at what depth the device is no longer visible from the surface.

b) Water Depth Measurement: This is carried out using a roll meter, which is submerged to the sea floor, and the depth is then measured.
c) Current Speed Data: This data is collected using a bottle and a string placed on the water's surface. Observations and measurements are made to determine how far the bottle is carried by the current over a certain period.
d) Coral Cover Data: This is obtained using the Line Intercept Transect (LIT) method. This method involves laying a 50-meter transect line without intervals.
e) Coral Fish Species Identification: This is done simultaneously with coral cover data collection. Coral fish species data are obtained by directly observing the fish.
f) Lifeform Types: These are identified concurrently with the collection of coral fish species and coral cover data along the transect line.

Carrying Capacity Data Capture Process
The ACC data is obtained from the coral reef distribution area at each location on Kelagian Besar Island, derived from Citra Satelit Sentinel 2A.

Interview With Local Community
The interview aims to observe something whose truth is being sought (Bondi, 2014). The data collection through interviews was conducted to understand the ecology, number of visitors, supporting infrastructure, and the legality of the local tourism management.

Observation Of Supporting Infrastructure
Infrastructure is a system consisting of facilities or services that are integral to human life and serve to meet basic human needs, such as economic and social requirements (Tzoulas et al., 2007). The observed infrastructure includes the existing facilities and the access road leading to Kelagian Besar Island.
Tourism Suitability Assessments

The process of analyzing the tourism suitability index is a comprehensive assessment of the suitability of a tourist area for two types of activities, snorkelling and diving (Romadhon et al., 2014). The suitability assessment for snorkelling employs 7 parameters, while for diving tourism, it utilizes 6 parameters is the formula used to determine the tourism suitability index (Shokri & Mohammadi, 2021):

$$TSI = \sum (Ni/N\ maks)\ x\ 100\%$$

Description:
TSI : Tourism Suitability Index
Ni : Value of i-th parameter (weight x score)
Nmax : Maximum value of a tourism category

The assessment on each criterion of suitability is determined based on the object's impact on the attractiveness of tourism. The greater the object's impact, the higher the parameter value assigned in (Shokri & Mohammadi, 2021).

The research is conducted by observing the existing parameters, to determine whether the collected data yields appropriate results or not. The parameters for assessing the suitability of diving ecotourism can be evaluated based on six parameters: coral reef depth, lifeform types, water clarity, coral species, coral community coverage, and current velocity. Meanwhile, parameters for assessing the suitability of snorkelling ecotourism can be calculated based on seven parameters: lifeform types, coral species, coral community coverage, coral reef width, water clarity, current velocity, and coral reef depth. Suitability for tourism classes is categorized as unsuitable with a score of <50%, conditionally suitable with a score of 50-75%, and suitable with a score of 75-100%. Data analysis is conducted after the data collection and processing process is completed.

Tourism Carrying Capacity

Area Carrying Capacity (ACC) is the maximum limit that a tourist area can sustain over a certain period without causing negative impacts on the ecosystem, both for humans and wildlife (Yusoh et al., 2023; Mohamad & Marzuki, 2018). By limiting the level of tourist visits within a specific timeframe, tourism management can be effectively carried out, ensuring that recreational activities can be enjoyed without harming the preservation of nature (Filza Nadilla Utari et al., 2023). The following is the formula used to determine the carrying capacity of the area (Shokri & Mohammadi, 2021):

$$ACC = K\ x\ \frac{Lp}{Lt}\ x\ \frac{Wt}{Wp} \qquad (2)$$

Description:
ACC = Area Carrying Capacity
Lt = The area size for a specific category
LP = The area/unit length of area that can be utilized
Wp = The duration utilized by visitors for each specific activity
Wt = The duration allocated by the area for daily tourism activities
K = The ecological capability of visitors per unit Area

Tourism Infrastructure Analysis

With the presence of sufficient supporting facilities, visitors are expected to feel more comfortable and secure while engaging in tourist activities. However, in the development of such infrastructure, it is necessary to consider the preservation of the ecosystem in the area (Mamirkulova et al., 2020). Therefore, the development of tourist attractions can be conducted sustainably, yielding positive benefits for visitors while still considering the protection and preservation of the natural environment (See Yulianda et al, 2019).

Integration Of Coral Reef Tourism Development

In the initial stage of information gathering, methods such as observation and mapping, documentation, functional object description, and aesthetic governance of coral reef ecotourism are utilized. This study employs comparative analysis, particularly focusing on ecotourism-supporting infrastructure. Based on this, infrastructure principles for coral reef ecotourism are hypothesized. These findings will serve as the foundation for the author to recommend further masterplan planning regarding the governance of coral reef ecotourism on Kelagian Besar Island.

RESULTS AND DISCUSSION

Tourism Suitability Index

Based on research conducted in the field, data on the suitability of snorkelling and diving tourism were obtained. The data obtained for snorkelling and diving categories are shown in the table below [See Table 1 and See Table 2].

The coral cover measurements on the island range from 23.3% to 87.6%. Location 1 has a coral cover percentage of 73.3%, location 2 has 87.6%, location 3 has 85.4%, location 4 has 23.3%, location 5 has 56.4%, location 6 has 54.6%, and station 7 has a coral cover percentage of 50.88%. The total identification results indicate the presence of 6-8 types of lifeforms, namely Coral Massive (CM), Coral Mushroom (CMR), Coral Foliose (CF), Coral Branching (CB), Coral Submassive (CS), Coral Millepora (CML), Acropora Branching (ACB), and Coral Encrusting (CE), which provide a captivating and beautiful sight for visitors.

Table 1: The Recapitulation of Snorkelling Activity Transaction Data

Indicator	station						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Water brightness (%)	100	100	100	49.42	85	100	100
Coral cover (%)	73.3	87.6	85.4	23.3	56.4	54.6	50.88
Lifeform types	6	7	7	8	6	6	8
Reef fish species	11	8	12	8	9	10	10
Current speed (cm/s)	10.1	7.2	13.3	7.6	8.2	5.2	4
Coral Depth (m)	6.5	5.6	4.5	4	5.5	9	6
Width of coral beds (m)	43	15	15	7	50	45	12

Table 2: The Recapitulation of Diving Activity Transaction Data

Indicator	station						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Water brightness (%)	100	100	100	49.42	85	100	100
Coral cover (%)	73.3	87.6	85.4	23.3	56.4	54.6	50.88
Lifeform types	6	7	7	8	6	6	8
Reef fish species	11	8	12	8	9	10	10
Current speed (cm/s)	10.1	7.2	13.3	7.6	8.2	5.2	4
Coral Depth (m)	6.5	5.6	4.5	4	5.5	9	6

The results contained in the summary table of transect data allow for the assessment of the Suitability Index for Tourism for snorkelling and diving activities [See Table 3 and see Table 4].

Analysis of the suitability of snorkelling category tourism in the waters of Kelagian Besar Island states the results with the category of unsuitable (S3) and diving category tourism with the category of conditionally suitable (S2.). The range of snorkelling IKW values obtained is between 28.07% - 77.19% and diving IKW range between 29.6-81.5%.

Area Carrying Capacity

The carrying capacity of an area is beneficial for regulating the number of visitors to a specific area within a certain period of time. To determine the carrying capacity value for snorkelling and diving categories, the area of tourism that can be utilized (Lp) is required [See Table 5].

Table 3: The Calculation of TSI Snorkelling Category

Parameter	Weight	Station						
		1	**2**	**3**	**4**	**5**	**6**	**7**
Water brightness (%)	5	5	15	15	5	5	5	5
Coral cover (%)	5	10	15	15	0	10	10	10
Lifeform types	3	3	6	6	6	3	3	6
Reef fish species	3	3	0	3	0	0	3	3
Current speed (cm/s)	1	3	3	3	3	3	3	3
Coral depth (m)	1	1	2	2	2	2	1	1
Width of coral beds (m)	1	1	0	0	0	1	1	0
N max	19	26	41	44	16	24	26	28
Percentage (%)		45.6	71.9	77.2	28.1	42.1	45.6	49.1
Category		S3	S2	S1	S3	S3	S3	S3

Table 4: The Calculation of TSI Diving Category

Parameter	Weight	Station						
		1	**2**	**3**	**4**	**5**	**6**	**7**
Water brightness (%)	5	5	15	15	5	5	5	5
Coral cover (%)	5	10	15	15	0	10	10	10
Lifeform types	3	3	6	6	6	3	3	6
Reef fish species	3	3	0	3	0	0	3	3
Current speed (cm/s)	1	3	3	3	3	3	3	3
Coral depth (m)	1	3	2	2	2	2	3	1
N max	19	27	41	44	16	23	27	28
Percentage (%)		50	75.9	81.5	29.6	42.6	50.0	51.9
Category		S2	S1	S1	S3	S3	S2	S2

Description:
Nmax : ∑ (weight x score)
TSI: S1 : Suitable (75-100%)
S2 : Conditonal Suitable (50-<75%))
S3 : Not Suitable (<50%)

Table 5: The Calculation of The Area/Length Unit of The Region That Can Be Utilized (Lp)

Tourism	K	The vast expanse of recreational activities (km^2)							Lt	Wt	Wp
		1	2	3	4	5	6	7			
Diving	2	64.0	90.3	13.1	121.3	73.6	171.2	163.4	2000	8	2
Snorkelling	1	32.6	50.4	27.2	23.0	40.1	105.4	70.0	500	6	3

The area available for diving tourism covers 796,755 m2, while for snorkelling tourism it is 358,636 m2. The assessment of the carrying capacity of the snorkelling and diving areas can be seen in. Figure 2.

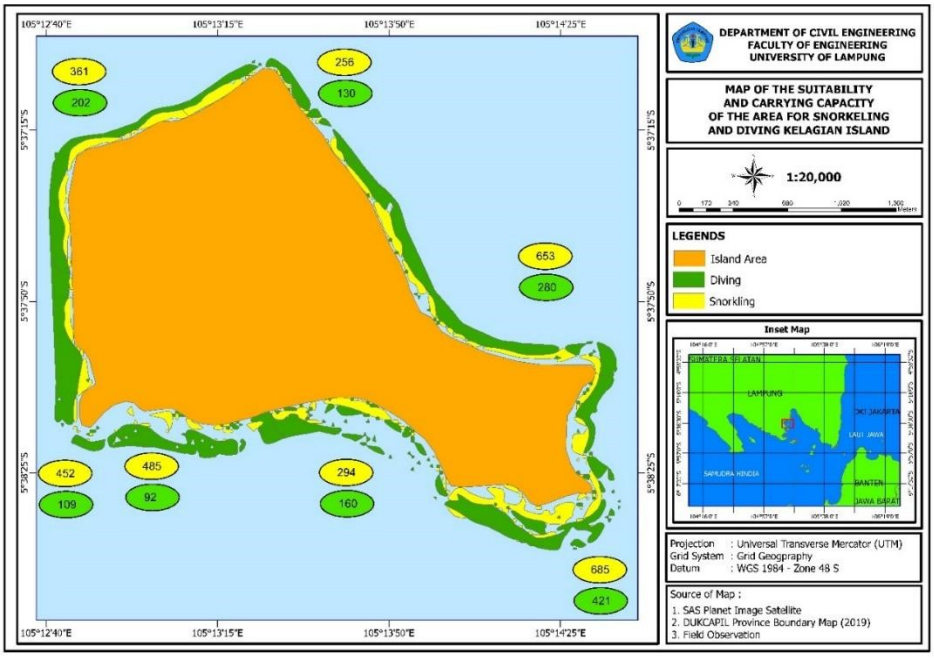

Figure 2: The Map of TSI And AAC On Kelagian Besar Island

The analysis of carrying capacity in the Kelagian Besar Island for snorkelling tourism reveals a maximum capacity of 256-685 people per day, whereas for diving tourism it is 92-421 people per day. These data are obtained from 7 stations, and the distribution map of maximum visitor capacity at each station can be seen in Figure 2.

Consequently, it is expected that the management can more effectively plan necessary actions to enhance tourists' experiences while preserving the environment.

Snorkelling and Diving Ecotourism Analysis

The analysis of the area's carrying capacity indicates that the coral reef area in Pulau Kelagian Besar reaches 114.54 hectares, predominantly featuring fringing coral. The diverse marine life, such as various types of fish and coral, serves as the main attraction for tourists visiting the island. This information is documented in a book discussing the impact of snorkelling routes on the coral reef. To enhance tourists' comfort, it's necessary to have a variety of coral types on Pulau Kelagian Besar, emphasizing the importance of coral diversity to enrich the tourists' experience. With this variety, tourists are more inclined to engage in snorkelling and diving activities.

From observations conducted at the 7 Stations listed in Figure 1, snorkelling and diving sites are present at all of these Stations. The highest coral cover percentage was recorded at Station 2, reaching 87.6%. Details regarding this coral cover can be found in Tables 4 and 5. Overall, the coral cover on this island is considered good, although there are two Stations showing signs of coral reef damage, namely Station 4. The lowest coral cover percentage was recorded at Station 4, reaching only 23.30%, which is attributed to a lack of regular maintenance. To maximize the potential in this area, it is recommended to conduct coral reef transplantation to enhance coral cover. This step will help preserve and enhance the suitability of coral reef ecotourism on Kelagian Besar Island.

The suitability analysis for snorkelling and diving activities, the ecotourism suitability index of the coral reefs on Kelagian Besar Island is classified as "not suitable" (S3). In comparison with similar research on Marsegu Island, Maluku, which utilized a similar analysis, the results indicate a Tourism Suitability Index (TSI) of 74.79% along the coast of Marsegu Island, categorized as "Suitable" (S1). This is due to a more optimal percentage of coral cover, visibility, and current speed in that area. The carrying capacity for diving and snorkelling activities on Kelagian Besar Island is 4582 people per day. Compared to the carrying capacity on Marsegu Island, Maluku, which has an area of 1023 hectares, its capacity reaches 4092 people per day. Therefore, as input for management, education is needed for visitors and local communities regarding snorkelling and diving activities to ensure the coral reef ecosystem remains intact and undamaged.

Supporting Infrastructure for Coral Reef Ecotourism

Based on direct field observations, the availability of supporting infrastructure can be seen in Table 10. The table indicates that the availability of infrastructure on Pulau Kelagian Besar is not evenly distributed. Given this condition, development of management should be undertaken to ensure the existing facilities are adequate.

The supporting infrastructure on this island is already quite good, but it still requires improvement and development, such as the lack of adequate resorts or accommodation, souvenir shops, and the absence of diving equipment rental facilities, which means visitors interested in snorkelling or diving need to bring their own diving gear.

Marine Ecotourism Development

According to the assessment of the tourism suitability index on Kelagian Island, it indicates that it falls into the category of not suitable (S3). This is due to the lack of coral fish species and the small number of live corals, resulting in a very low tourism suitability score. By collaborating with management or government, it is hoped that the potential of tourism on this island can be enhanced and the tourism industry, especially marine ecotourism, can be developed.

There are several efforts that can be made to develop marine ecotourism activities, including:

a. Conducting coral reef transplantation and maintaining the quality of the underwater ecosystem aimed at increasing the tourism suitability index, especially regarding coral fish species and the number of life forms.
b. Improving the management of supporting infrastructure to make visitors more comfortable to engage in tourism activities (Wijaya, 2016). Some examples include providing diving equipment rental facilities, improving road access to tourist stations, and providing public facilities such as toilets, prayer rooms, and accommodations.
c. Promoting environmentally friendly marine tourism on social media. This promotion includes information about tourist attractions on the island, availability of transport boats, and professional guides to minimize environmental damage and ensure the safety of tourists.

Marine Ecotourism Integration Planning

The development planning of ecotourism on this island is reviewed based on accessibility and amenities. After observation, the results obtained are in the form of fairly good infrastructure conditions, but improvements and development are still needed for the existing infrastructure on the island. Recommendations for infrastructure development planning need to be made before creating a master

plan so that the results obtained can increase the number of tourists to Kelagian Besar Island [See Figure 3].

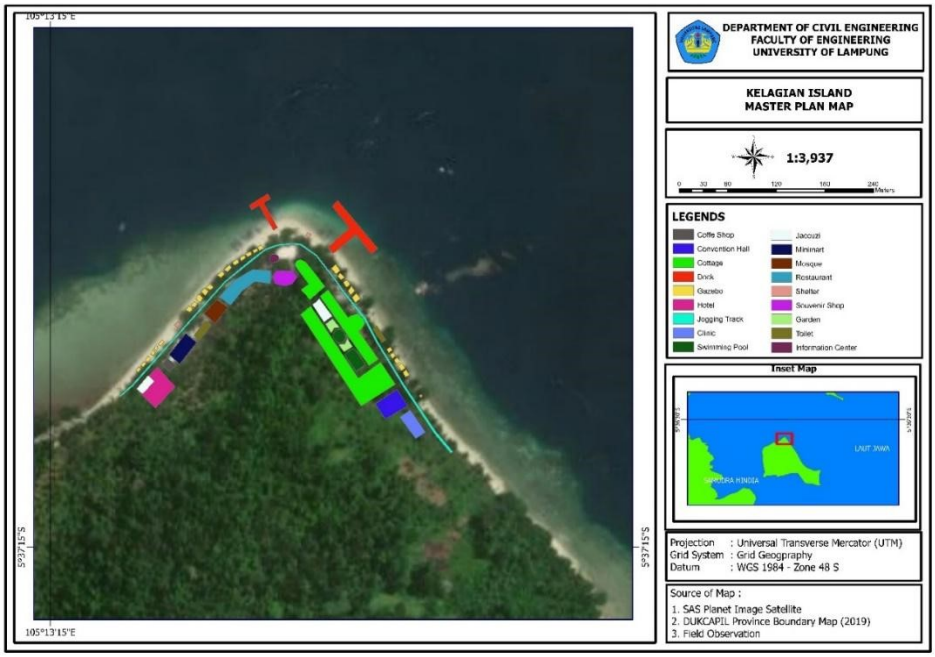

Figure 3: Masterplan Kelagian Besar Island

The picture illustrates that the development of infrastructure facilities can be centralized in the northern part of the island, aiming to preserve the island's environment so that tourists can still visit and explore the island without harming the environment. It is hoped that the recommendations from the existing infrastructure will serve as a reference or consideration for tourism management or relevant authorities, thereby fostering the continuous improvement of ecotourism on the island, both economically and socially.

CONCLUSION

The conclusion is that the overall suitability analysis of tourism falls into the category of not suitable (S3), and the carrying capacity of the area for snorkelling and diving tourism is 4582 people per day. Therefore, there is a need to improve the quality of coral reefs, as well as the supporting infrastructure for ecotourism management on the island.

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