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Sustainability Analysis Management of Coral Community and Gili Genting Island Sumenep Madura, Indonesia

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ABSTRACT

This study aimed to identify the condition of coral lifeforms and the sustainability of tourism management on Gili Genting Island, Madura. The data used are from surveys and questionnaires conducted in July and August 2024. The research employed both qualitative and quantitative methods, utilizing the Underwater Photo Transect technique at 4 stations for coral assessment, and the sustainability status of the island's tourism using Multidimensional Scaling (MDS) with a modified version of the Rapid Appraisal Index Rap-fish, called Rap-island. The evaluation was based on five dimensions: ecological, economic, social, legal-institutional, and infrastructure. The results showed that the highest percentage of live corals was found at station 4, at 83.02%, followed by station 3 at 82.06%, the lowest being at station 2 with 65.36%, and station 1 with 66.8%. The lifeforms identified consisted of 5 species of Acropora and 7 species of non-Acropora. Acropora Branching dominated with 34.69%, while non-Acropora was dominated by Coral Massive at 7%. The percentage value of lifeforms from Underwater Photo Transect was 55.37%, which is higher than the Line Intersect method, which only reached 13.54%. The sustainability status of Gili Genting Island's tourism is categorized as moderately sustainable (55.7). The index values for the five dimensions are as follows: ecological dimension, moderately sustainable (74.7); economic dimension, less sustainable (49.07); social dimension, moderately sustainable (53.6); legal and institutional dimension, less sustainable (46.7); and infrastructure dimension, very sustainable (83.5).

INTRODUCTION

Gili Genting is one of the islands among the 115 located in Sumenep Regency, East Java. This island has large coral reefs and mangrove areas, making it a potential destination for island-based tourism development **(Rosyidah *et al.*, 2021; Ustadi *et al.*, 2022; Wayhudi *et al.*, 2023; Silvia & Muhsoni, 2024)**. Gili Genting holds significant

potential for the development of dive ecotourism, snorkeling ecotourism, and beach ecotourism. The coral ecosystem, which serves as an underwater tourism attraction, is found at a depth of 3 meters with a density of 5.9-7.6 individuals/m² from 14 species, and a coral cover percentage of 14.5%, indicating a high recruitment category **(Ustadi *et al.*, 2022; Idris *et al.*, 2023)**.

The increasing growth of dive, snorkeling, and island tourism in Gili Genting has impacted the local and regional economy **(Munandar *et al.*, 2023)**, but it also poses a serious threat to the coral reef ecosystem. This trade-off phenomenon has led to environmental degradation and a decline in the sustainability of the area. The deterioration of water quality due to increased activities in and around the tourism area can lead to the accumulation of organic materials, toxic compounds, and other harmful substances, heavy metals, aquatic fertility, and a decrease in biodiversity **(Davis & Tisdell, 1996; Wilson *et al.*, 2006; Assyifa *et al.*, 2023)**, as well as an increase in waste volume. Ecotourism is a sustainable form of tourism that focuses on the management of nature, culture, and environmental conservation **(Azizah *et al.*, 2021)**.

The potential of Gili Genting as an ecotourism destination requires a sustainability evaluation for its development. The analysis of sustainability status of tourism management was carried out using the RAPFISH (Rapid Appraisal for Fisheries) method and its modifications **(Hermawan *et al.*, 2006; Erwina *et al.*, 2015; Ustadi *et al.*, 2022; Idris *et al.*, 2023; Farid *et al.*, 2024; Silvia & Muhsoni, 2024)**. Therefore, this study aimed to analyze the sustainability status of tourism management on Gili Genting Island, Sumenep, across ecological, economic, social, legal and institutional, infrastructure, and multidimensional dimensions.

MATERIALS AND METHODS

Study area

This research was conducted from July to August 2024, located in Gili Genting Island Sumenep, East Java Indonesia (7°10'31.3' S and 113°55'18.1'E) (Fig. 1). The coral sampling technique was conducted using purposive sampling around the location, resulting in 4 observation stations for ecological dimension data. Meanwhile, data for the social, economic, legal-institutional, and infrastructure dimensions were collected through questionnaires administered to respondents representing community leaders, visitors, fishermen representatives, village government representatives, youth groups, traders/business owners, and ferry boat captains.

Samples collection, identification of coral reef

Coral reef observation uses Underwater Photo Transect (UPT) methods. UPT method at 3 until 5m depth collects data on the condition of coral reefs using an underwater digital camera and a photo frame measuring 58 x 44cm with a transect length of 50m **(Giyanto, 2013)**. The number of photos for each transect is 50 images with a total

of 500 identified images. While the total percentage of lifeform cover is categorized based on the categrization of **Gomez and Yap (1988)**.

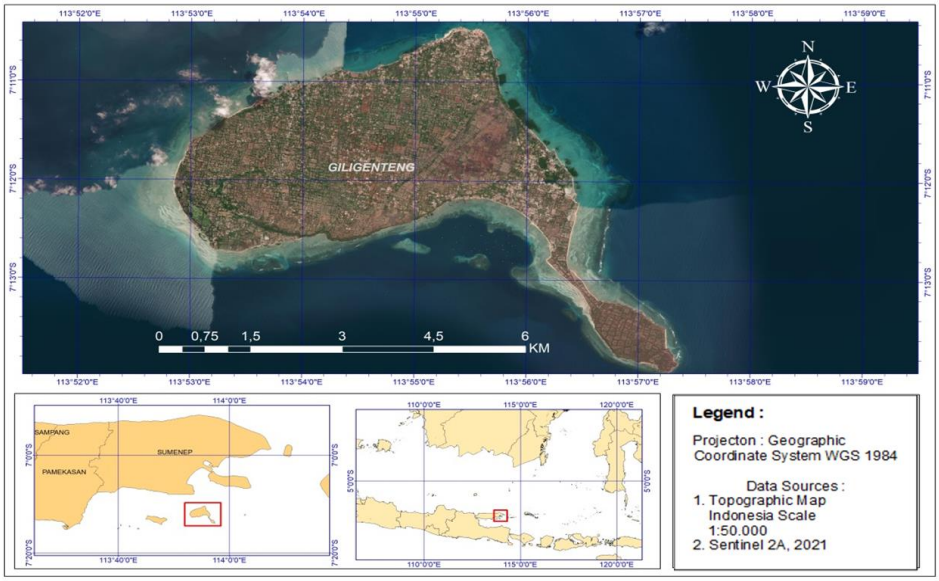

Fig. 1. Map of sampling locations

The photos obtained were analyzed using CPCe (Coral Point Count with Excel extension) software. CPCe is capable of calculating coral cover in the study area. For each transect frame, 30 (thirty) matrices of points were randomly distributed. These points were then identified by substrate type and/or coral reef species. The process of identifying coral species involves selecting the coral species code, as shown in Table (1). Species code data for each transect frame were stored in a .cpc file, which contains the image file name, point coordinates, and identified data codes, generated automatically via an Excel spreadsheet. Meanwhile, the collected transect data were statistically analyzed to provide estimates of species diversity in the area of interest **(Suharsono & Sumadhiharga, 2014)**

Table 1. Coral reef and/or substrate data codes in CPCe

Code	Description
LC	*Live Coral*
AC	*Acropora*
NA	*Non Acropora*
DC	*Dead Coral*
DCA	*Dead Coral with Algae*
SC	*Soft Coral*
SP	*Sponge*
FS	*Fleshy Seaweed*
OT	*Others*
R	*Rubble*
S	*Sand*
SI	*Silt*
RK	*Rock*

The analysis of growth forms was categorized into two main groups: live coral and dead coral. The assessment of coral cover obtained from the life form evaluation was calculated according to **Manuptty and Djuwariah (2009)** using the following formula:

$$\% \text{ Live Coral} = \frac{\text{Number of Substrate Categories}}{\text{Total Number of Categories}} \times 100\%$$

According to the Minister of Environment Decree No. 4 of 2001 regarding the percentage of live coral cover, the criteria for coral condition are as follows:
0% – 24.9%: Poorly damaged and moderately damaged
25% – 44.9%: Fairly damaged
50% – 74.9%: Good coral
≥75%: Very good coral

Identification and determination of sustainability attributes

Based on all the attributes and the data requirements needed to assess the sustainability of the Gili Genting Island tourism area, a total of 40 attributes have been identified and categorized into five dimensions: ecological (n = 11), economic (n = 5), social (n = 9), infrastructure (n = 7), and legal and institutional (n = 8; Table 2). These attributes represent various threats that impact the status of the island's tourism.

This classification allows for a comprehensive evaluation of the sustainability of the tourism management, considering different aspects of the environment, economy, society, infrastructure, and regulations.

Table 2. Dimensions and attributes of ecological, economic, social, institutional infrastructure and legal sustainability

Dimensions and attributes	Assessment	Score
	Ecology	
Types of coral fish (species)	Not suitable at all (<10 species)	1
	Not suitable (10-20 species)	2
	Conditionally suitable (20-75 species)	3
	Suitable (>75 species)	4
Water brightness (m)	<20	1
	50-20	2
	80-50	3
	>80	4
Live hard coral cover (%)	Not suitable at all (<10%)	1
	Not suitable (10-20%)	2
	Conditionally suitable (20-75 %)	3
	Very suitable (>75)	4
Beach width (m)	<3	1
	10-3	2
	15-10	3
	> 15	4

Dimensions and attributes	Assessment	Score
Water depth (m)	>10	1
	6-10	2
	3-6	3
	<3	4
Current speed (cm/sec)	>0.51	1
	0.37-0.51	2
	0.17-0.37	3
	>0.17	4
Availability of fresh water (distance/km)	No fresh water sources	1
	> 1	2
	0.5 - 1	3
	<0.5	4
Beach slope (0)	>45	1
	25-45	2
	10-25	3
	<10	4
Dangerous biota	Sharks	1
	Sea Urchins and Rays	2
	Sea Urchins	3
	None	4
Beach type	Rocky Mud	1
	Rocky Black Sand	2
	Slightly White Sand	3
	White Sand	4
Beach land closure	Mangrove	1
	Tall shrubs	2
	Medium shrubs	3
	Coconut Plantation, Open Land	4
Social		
Level of conflict in the utilization of tourism in Gili Genting	Very frequently (every week)	1
	Frequently (every month)	2
	Slight (1-2 times a year)	3
	None	4
There Are Still Fishermen Using Potas or Explosives for Fishing	Available	1
	Decline	2
	Constant	3
	None	4
Community understood the importance coral reefs to protected the coastline and village from sea storm	Do not understood	1
	Slightly understood	2
	Understood	3
	Fully understood	4
Community understood that protecting coral reefs ensures the sustainability of	Do not understood	1
	Slightly understood	2

Dimensions and attributes	Assessment	Score
next generations' livelihoods in the village	Understood	3
	Fully understood	4
Level of education	Unschooling	1
	Graduated from Elementary School (SD)	2
	Graduated from Junior High School (SLTP)	3
	Graduated from High School or higher	4
Community awareness that damage coral reefs or the environment to punishment by law	Do not know	1
	Disagree	2
	Agree	3
	Strongly agree	4
Community awareness that fishing around coral reefs needs to be regulated to allow fish and coral to grow	Do not know	1
	Disagree	2
	Agree	3
	Strongly agree	4
Community collecting coral reefs for building materials or other use	Frequently (done once a week)	1
	Occasionally (done once a month)	2
	Rarely (done once a year)	3
	None	4
Participation in coral reef protection	None	1
	Community monitoring activities	2
	Community activities and initiatives	3
	Community monitoring, protection and initiatives	4
Economy		
Livelihoods of the majority of the community around the tourism area	Sand/coral miners	1
	Fishermen/ salt or fish farmers	2
	Farmers	3
	Tourism Sector	4
Contribution of tourism to village development	None	1
	Low (< 1 million/month)	2
	Medium (1-5 million/month)	3
	High (> 5 million/month)	4
Utilization of tourism in cooperation with outsiders (profit transfer/ownership transfer) and which is more dominant	Outsiders	1
	Outsiders slightly larger	2
	Balanced between outsiders and locals	3
	Locals larger	4
Income of the community from the tourism sector (Rp. 1,398,000 = Minimum wage for Sumenep Regency)	Below < Rp 500,000	1
	Between Rp 500,000 - Rp. 1,000,000	2
	Between Rp 1,000,000 - Rp 1,500,000	3
	Above Rp 1,500,000	4
Labor absorption in the tourism sector at Gili Genting	Very low (none at all)	1
	Low (only certain individuals)	2
	Medium (half of the Gili Labak residents)	3
	High (almost all residents)	4

Dimensions and attributes	Assessment	Score
Legal and Institutional		
Private investors providing capital for tourism development	None	1
	Low (1-5 people)	2
	Medium (6-10 people)	3
	High (more than 10 people)	4
Government institutions' role in tourism management	Small (none)	1
	Medium (present but inactive)	2
	Large (present)	3
	Very large (present and active)	4
Cooperative institutions	None	1
	Small (1-5 people)	2
	Medium (6-10 people)	3
	High (10-15 people)	4
Bank institutions helping with capital	None	1
	Small (only 1-5 people receive capital)	2
	Medium (6-10 people receive capital)	3
	High (almost all people receive capital)	4
Security institutions (maritime) involved in sea monitoring	None	1
	Small (every 6 months)	2
	Medium (once a month)	3
	High (once a week)	4
Fishermen/community groups on Gili Genting Island	None	1
	Slight (some and no activity)	2
	Moderate (some and rarely any activity)	3
	High (some and every week there is activity)	4
Resource management regulations on Gili Genting	None	1
	Limited (1)	2
	Available (1-2)	3
	Widely Available (>2)	4
Involvement of fishermen (in preparation), fishermen are involved in verifying data and information	None	1
	Low	2
	Medium	3
	High	4
Infrastructure		
Transportation to tourist attractions	None	1
	Difficult	2
	Currently	3
	Easy	4
Public toilets are available at tourist attractions	None	1
	Limited availability and poorly maintained	2
	Available but limited	3
	Available	4

Dimensions and attributes	Assessment	Score
There are places of worship available at tourist attractions	None	1
	Available but not maintained	2
	Available but limited	3
	Available in very sufficient	4
Equipment rental facilities available for tourism (swimming, snorkeling or others)	None	1
	Available but most have been damaged	2
	Available but limited	3
	Available in very sufficient	4
Tourist support facilities are available (gazebo/tent/trash can)	None	1
	Available but most have been damaged	2
	Available but limited	3
	Available in very sufficient	4
Support for road facilities and infrastructure	None	1
	Available but difficult to access	2
	Available, easy access but expensive	3
	Available, easy access and cheap	4
Accommodation available at tourist attractions (homestay/other)	None	1
	Available but most have been damaged	2
	Available but limited	3
	Available in very sufficient	4

Attribute Assessment

The second step of the analysis was to define and score the attributes according to RAPFISH method **(Alder *et al.*, 2000; Good *et al.*, 2000)**, where a "poor" score indicates the worst condition for island tourism, and a "good" score represents the most favorable condition. The attribute assessment in this study follows the method formulated by **Good *et al.* (2000)** and **Hershman *et al.* (2000)**. The score for each attribute depends on its position within the range from poor to good.

Multidimensional scaling (MDS)

The MDS analysis uses the Rapid Appraisal or Rap-fish method (Rapid Assessment Techniques for Fisheries) in fisheries **(Pitcher & Preikshot, 2001)**, which is modified into Rap-island for island tourism. The procedure for this method was as follows **(Fauzi, 2019)**:

1. Review attributes (including various categories and scoring).
2. Identify and define attributes.
3. Scoring (constructing reference points for good and bad, as well as anchors).
4. Multidimensional scaling ordination (for each attribute).
5. Leverage analysis.
6. Sustainability analysis.

The sustainability score points were visualized in two dimensions along horizontal and vertical axes using a rotation method. The points were marked with a 0% score (poor) and a 100% score (good), divided into four sustainability status categories with the

following criteria: 0.00-25.00: Not sustainable; 25.01-50.00: Less sustainable; 50.01-75.00: Moderately sustainable; 75.01-100.00: Very sustainable

The stress value analysis must be <25, as it serves as a model validation technique for MDS, with stress values categorized as follows: >20: Poor; 10-20: Sufficient; 5-10: Good; 2.5-5: Very good

Leverage analysis, shown as a bar diagram, identifies the stability effects during ordination and shows the percentage of attribute changes. Attributes with the highest percentage are considered sensitive and influence the sustainability status score.

RESULTS

1. Condition of the Genting Gili Reef Ecosystem

During the observation period at the Gili Genting research site, a total of 12 coral species were identified, consisting of 5 species of Acropora corals and 7 species of non-Acropora corals. The dominant Acropora coral species at the site was Acropora Branching (ACB) with a coverage of 34.69%, while the dominant non-Acropora species was Coral Massive (CM) with a coverage of 7% (Fig. 2). The identified coral species during the observation on Gili Genting Island include: Acropora Branching (ACB), Acropora Submasive (ACS), Acropora Encrusting (ACE), Acropora Tabulate (ACT), Acropora Digitate (ACD), Coral Branching (CB), Coral Massive (CM), Coral Encrusting (CE), Coral Submassive (CS), Coral Foliose (CF), Coral Musroom (CMR), Coral Milepora (CME), Dead Coral (DC), Rubble (R), Sand (S), Rock (RK) (Fig. 3).

The highest percentage of live coral cover was found at station 4 with 83.02%, followed by station 3 with 82.06%, while the smallest coverage was observed at station 2 with 65.36%. Station 1 had a live coral coverage of 66.8%. The coral cover values greater than 50% but less than 74.9% indicates that the coral coverage falls within the Good and Very Good categories. This condition is supported by the water quality parameters of Gili Genting Island, which still meet the standards for beach and island tourism **(Ustadi *et al.*, 2022)**. Additionally, coral cover percentages lower than 40%, especially when compared to the percentage of abiotic cover, are generally categorized as damaged **(Yunandar, 2011; Ghallab, 2020; Morais & Bellwood, 2020; Herawati *et al.*, 2023; Silvia & Muhsoni, 2024)**. The percentage of live coral cover at Gili Genting, measured using the Underwater Photo Transect (UPT) method, was found to be 55.37% (Fig. 4).

Fig. 2. Acropora and non-acropora corals on Gili Genting Island

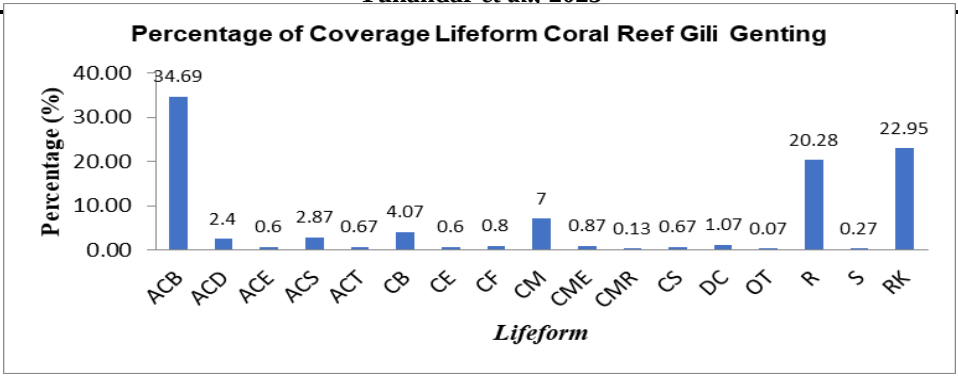

Fig. 3. Condition of coral reef lifeforms on Gili Genting Island

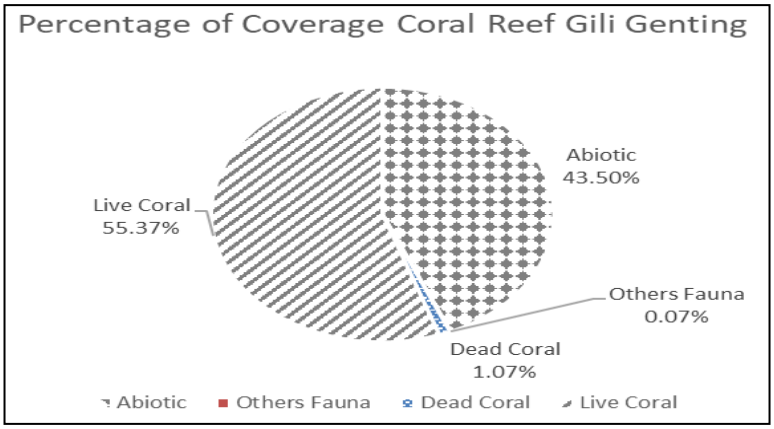

Fig. 4. Coral reef condition of Gili Genting Island

2. Sustainability of Gili Genting Island tourism, Sumenep Regency

The results of the Rap-Island analysis, which is a modification of the Rap-fish method, yielded a multidimensional sustainability index for the management of Gili Genting Island tourism. This analysis evaluated five dimensions: ecology, economy, social factors, legal and institutional aspects, and infrastructure. The overall sustainability index score for Gili Genting Island tourism management was 55.7 (Fig. 5). This value indicated that the tourism management of Gili Genting Island falls within the moderately sustainable category, as it falls within the scale of 50.01-75.00.

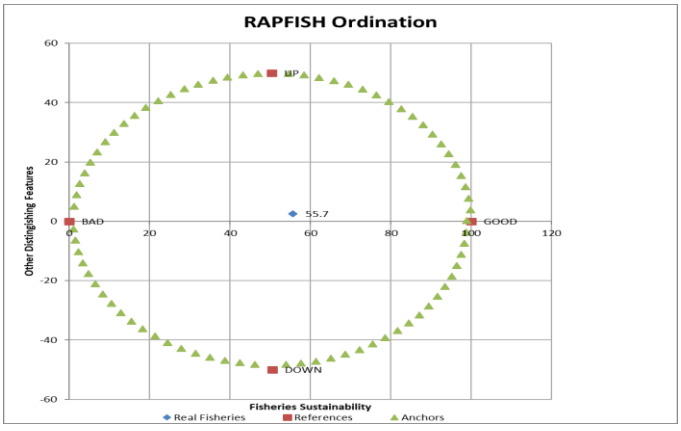

Fig. 5. Results of the multi-dimensional Rap-Island analysis of Gili Genting island tourism management

The tourism management of Gili Genting Island, which is currently categorized as moderately sustainable, requires a closer look at each dimension to identify areas for improvement in order to achieve a more sustainable tourism management approach. Based on the results of the Rap-Island ordination method across all relevant dimensions (Fig. 6), the legal and institutional dimension, along with the economic dimension, are categorized as less sustainable. In contrast, the social and ecological dimensions are considered moderately sustainable, while the infrastructure dimension is classified as very sustainable.

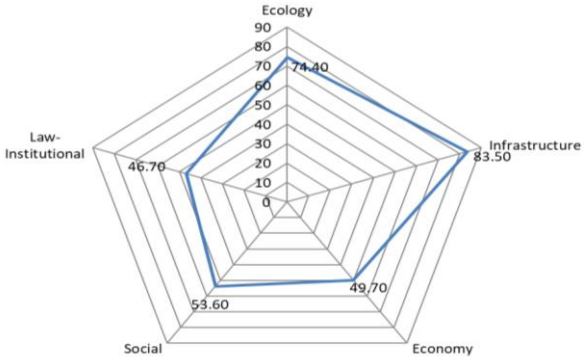

Fig. 6. Multidimensional sustainability flyer diagram for Gili Genting island tourism

This condition indicates that tourism management on Gili Genting Island is not yet optimal, as it has not achieved a balanced performance across the five assessed dimensions. The multidimensional index values for Gili Genting Island's tourism management are presented in Table (3). Additionally, the stress values and coefficients of determination for each dimension related to island tourism management are also provided in Table (3).

Table 3. Statistical values from the Rap-Island analysis results on the five dimensions

Dimensions of Sustainability	Sustainability Index Value	Information	Statistical Value		
			Strees (S)	R^2	Iteration
Ecology	74.7	Moderate sustainability	0.13	0.95	2
Economy	49.07	Less sustainability	0.18	0.93	2
Social	53.6	Moderate sustainability	0.14	0.94	2
Legal and Institutional	46.7	Less sustainability	0.16	0.94	2
Infrastructure	83.5	Very sustainability	0.13	0.95	2

Stress value <0.25 means goodness of fit; R^2 value 94% or >80%: the contribution is very good.

Based on the results of the Rap-Island analysis, it shows that the stress value (S) rangeed between 0.13-0.18 (13-18%) and the coefficient of determination (R2) value ranged from 0.93-0.95 (93-95%). This shows that the attributes in all dimensions of sustainability in Gili Genting island tourism management are quite accurate and can be scientifically justified. According to the MDS procedure, the stress value is <25%

(S<25%) and the (RSQ) value is close to 1.0. Rap-Island has fulfilled the goodness of fit with a given confidence interval correlation of 95%.

2.1. Ecological dimensional

The results of Rap-island's analysis of eleven ecological dimension attributes were 74.7%, meaning it is quite sustainable (Fig. 7), so that island tourism activities in the categories of diving, snorkeling and beach tourism are currently in suitable conditions and have not exceeded the carrying capacity or disrupted resource sustainability which are found in coastal areas and on the island of Gili Genting. The position of sustainability in the ecological dimension shows that the villages of Bringsang, Gedugan, Galis and Aenganyar are all in the fairly sustainable category. Meanwhile, the results of the leverage of attributes that influence the sustainability status assessment category showed that the attributes have a strong influence on the ecological sustainability status assessment category, namely coral fish species, beach width, water depth, and beach type have a relative level of sensitivity, high in island tourism management, while the availability of fresh water has a relatively lower level of sensitivity than other attributes.

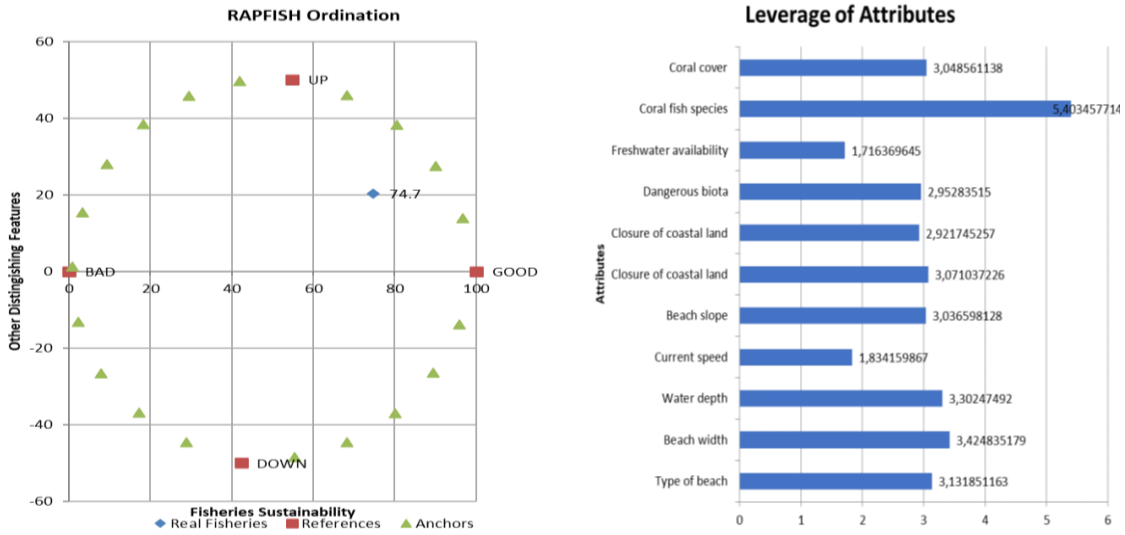

Fig. 7. Sustainability index value in the ecological dimension and attributes in Root Mean Square (RMS)

2.2. Social dimensional

The results of the analysis show that the sustainability index value is 53.6%, meaning it is quite sustainable (Fig. 8). Based on the results of the leverage analysis, 3 attributes were obtained that were sensitive to the value of the sustainability index in the social dimension, namely (1) current protection of coral reefs ensures the sustainability of the livelihoods of future generations in this village, (2) there are still potash and bomb users for catching fish at this time, and (3) participation in protecting coral reefs.

Fig. 8. The value of the social dimension of the sustainability index and attributes in Root Mean Square (RMS)

2.3. Economical dimensional

The results of the analysis using Rap-Island on five economic dimension attributes obtained a sustainability index value of 49.07%, meaning it is less sustainable (Fig. 9). Four attributes that influence the sustainability index value from the economic dimension are (1) community income from the tourism sector according to the Sumenep Minimum wage, (2) utilization of tourism in collaboration with outsiders, (3) employment in the tourism sector, and (4) the livelihood of most of the people around the tourist area. The four attributes in the economic dimension mutually influence each other in the development of island of Gili Genting, Sumenep.

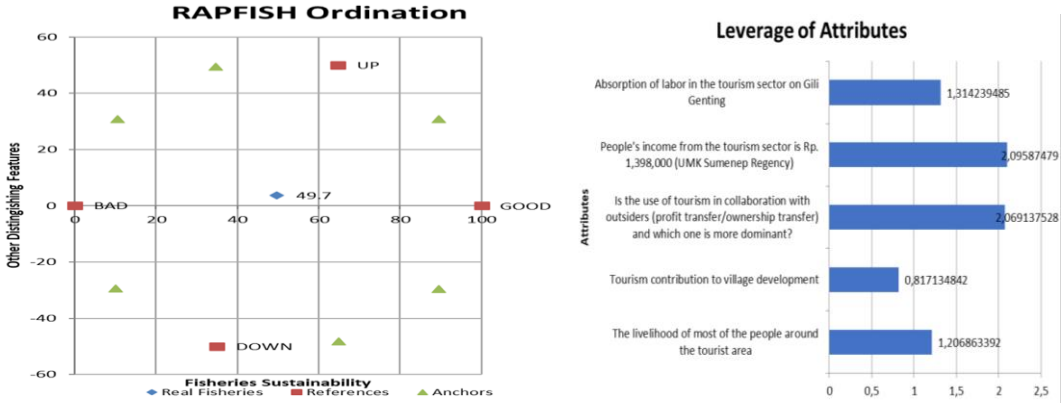

Fig. 9. The value of the economical dimension of the sustainability index and attributes in Root Mean Square (RMS)

2.4. Legal and institutional dimensional

The results of the analysis using Rap-Island for eight legal and institutional dimension attributes were 46.7% with less sustainable status (Fig. 10). This index value shows that legal and institutional implementation in developing island tourism on Gili Genting is still minimal.

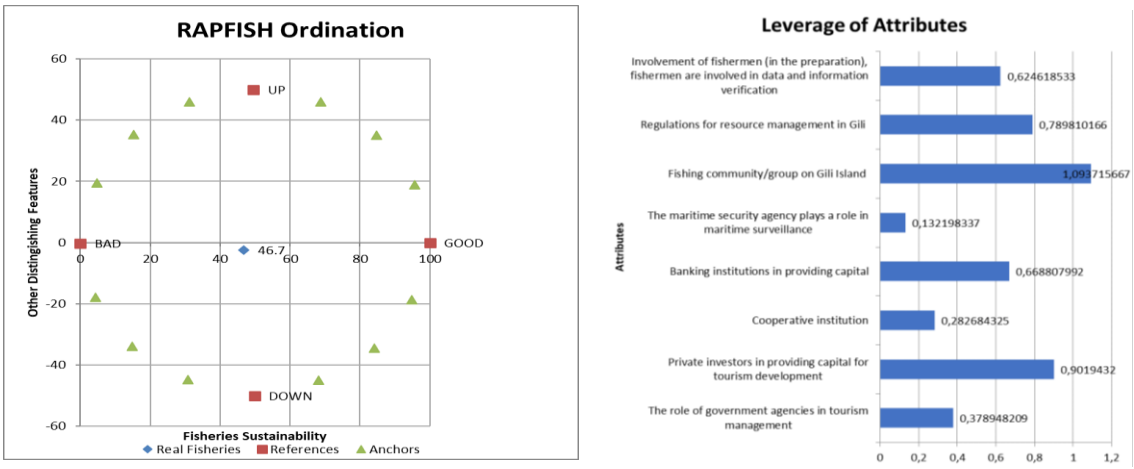

Fig. 10. The value of the legal and institutional dimension of the sustainability index and attributes in Root Mean Square (RMS)

Based on the results of the leverage analysis, it was obtained that 2 attributes were sensitive to the sustainability index value of the legal and institutional dimensions, namely (1) fishermen/community groups on Gili Genting Island, and (2) personal capital in providing tourism development.

2.5. Infrastructure dimensional

The results of the analysis using Rap-Island on seven infrastructure dimension attributes obtained a sustainability index value of 83.5% with very sustainable status (Fig. 11). Meanwhile, the results of the leverage analysis are in the infrastructure dimension.

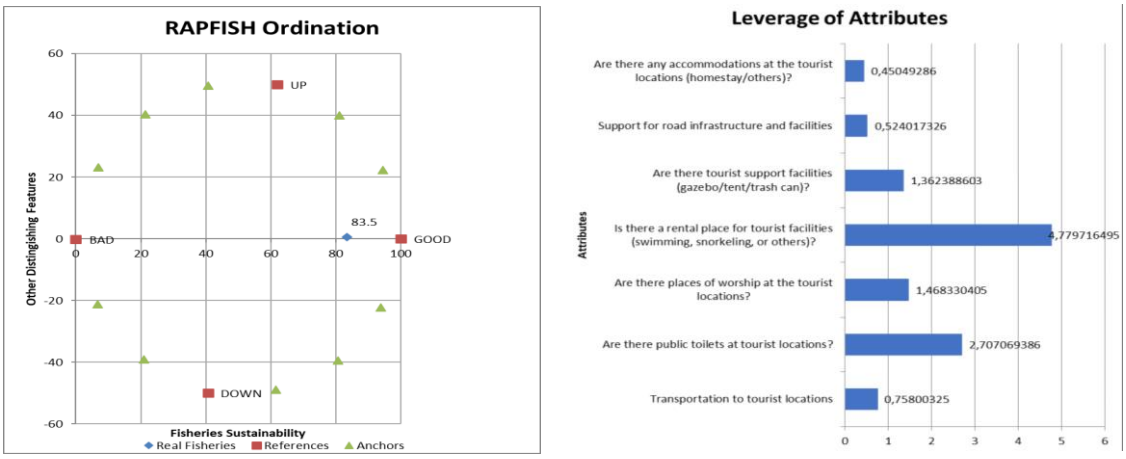

Fig. 11. The value of the infrastructure dimension of the sustainability index and attributes in Root Mean Square (RMS)

DISCUSSION

The percentage of coral cover can be used as an indicator of coral health, especially the dominance of Acropora species compared to non-Acropora. Coral responses to

environmental oceanography vary; areas with high sedimentation have slower growth or foliose forms and tend toward massive forms **(Chappel, 1980; Van Woesik, 2002)**. In contrast, in clear waters with low sedimentation, branching and tabulate forms are more commonly found. Massive corals tend to grow more in outer reefs with currents and waves **(Zamani *et al*., 2011)**, which influence the shape of coral colonies. Corals living in areas sheltered from waves tend to have slender, elongated branching shapes, while in areas with strong waves, growth forms tend to be shorter, stronger, creeping, or submassive. The coral cover percentage obtained using the Underwater Photo Transect method is 4 times more accurate than the manual Line Intersect method. This finding aligns with the studies of **Giyanto (2013)**, **Assyifa *et al*. (2022)**, **Balumpapung *et al.* (2022)** and **Munandar *et al*. (2023)**. The highest coral branching cover (ACB) was found to be 34.69%, indicating a habitat that is calm, with minimal wave influence, a salinity of 30-32‰, and a temperature of 30°C, which supports coral life **(Nybakken, 2007; Supriharyono, 2007)**. The rubble coral cover was 20.28%, indicating fishing activities using explosives, as well as cyanide use, which causes coral breakage and poor growth **(Myers & Raymundo, 2009; Sala *et al.*, 2024)**.

The principle of sustainable management is a balance between ecological, economic, social, legal, institutional, and infrastructure dimensions, which are analyzed using Multidimensional Scaling (MDS). The current sustainability status of the Gili Genting waters is still categorized as fair, so improvements need to be made, especially in the economic, social, and legal-institutional dimensions, while maintaining the ecological and infrastructure dimensions, which are the tourism assets of the island. The same category was obtained for the management of the Gili Sulat-Gili Lawang Conservation Area in East Lombok Regency **(Ismane *et al*., 2018)**, and for the Marine Protected Areas (MPAs) such as Blongko in South Minahasa, Sebesi Island in South Lampung, and Harapan Island in the Thousand Islands **(Andronicus *et al*., 2016)**. Improvements are made by enhancing attributes that have a positive impact and reducing attributes that could lower the sustainability index. This sustainability analysis has been statistically validated, with a stress value (S) of less than 0.25 **(Kavanagh, 2001; Alvi *et al*., 2018)** and a coefficient of determination (R) considered good, ranging from 80 to 100% **(Fauzi & Anna, 2002)**. The Monte Carlo technique shows that the results of the Rap-Island ordination analysis are stable and unaffected, both in individual dimensions and the combined overall sustainability dimensions.

Ecological dimensions

The index value in the ecological dimension falls into the 'fairly sustainable' category, but there are still attributes with high sensitivity that should be prioritized for improvement. The coral fish species attribute is correlated with coral recruitment (juveniles), which is the most sensitive to the sustainability index of the area. Coral fish species are a driving attribute in the ecological dimension; if the growth of coral fish species can be improved with artificial reef **(Folpp *et al.*, 2011; Folpp *et al.*, 2020)**, the

sustainability index value can also increase. Coral depletion causes a decline in the abundance of carnivorous fish and an increase in mortality, depending on the sensitivity of fish to corals as feeding and shelter sites **(Wilson *et al.*, 2006)**. A high percentage of coral cover will influence the resources utilized, such as fish abundance and dive tourism. Other important factors that significantly affect the sustainability index in island tourism development are the number of coral fish species, beach width, and water depth. Attributes that need to be maintained because they contribute positively to the sustainability index include the availability of freshwater throughout the year, especially on Gili Genting Island.

Social dimensions

The social dimension falls into the fairly sustainable category based on its index value. The attributes with high sensitivity are: (1) coral reef protection, which currently ensures the sustainability of livelihoods for future generations in the village, (2) the ongoing use of potassium and bombs for fishing, and (3) participation in coral reef conservation. These attributes need to be managed by improving current coral reef protection through active community involvement in mentoring activities. The elimination of potassium and bomb fishing can be achieved by offering alternative employment, such as working as a diving tour guide, renting diving and snorkeling equipment, fishing, cottages, tents, small shops, and boat transportation.

Economic dimensions

The assessment based on the index value from the economic dimension falls into the unsustainable category. The attributes that influence the sustainability index value from the economic dimension are: (1) the income of the community from the tourism sector in accordance with the Sumenep minimum wage, (2) the utilization of tourism in collaboration with external parties, (3) employment absorption in the tourism sector, and (4) the livelihoods of the majority of the local community around the tourism area. Collaboration with external parties in tourism increases the number of visitors, thereby ensuring the sustainability of tourism businesses on Gili Genting Island. The low sustainability status in the economic dimension is caused by poor marketing and the transportation distance from Surabaya and Bangkalan, which takes about 5-6 hours, plus the crossing still relies on traditional fishing boats.

Legal and institutional dimensions

The legal and institutional dimension falls into the unsustainable category due to attributes that have a sensitive impact on sustainability, namely: (1) the fishermen/community groups on Gili Genting Island, and (2) personal capital in providing tourism development. The level of community awareness in organizing or grouping as fishermen has become solid, with the involvement of all fishermen in institutions or groups. The process is carried out through mentoring activities to support institutional strengthening, human resources, and knowledge in accordance with local

wisdom. The social capital owned by the community, based on religious commonality, allows meetings to discuss issues faced by the fishermen to be held at the mosque.

Infrastructure dimensions

The infrastructure dimension falls into the highly sustainable category with attributes that influence sensitivity, namely: (1) the availability of rental facilities for tourism equipment, (2) the availability of public toilets at tourist sites, (3) the availability of places of worship at tourist sites, and (4) the availability of supporting facilities for tourism. The comparison between the number of visitors and the lack of infrastructure services is an obstacle to developing tourism on this island. Infrastructure plays a role in increasing tourist visits **(Gier *et al.*, 2017; Deely *et al.*, 2022; Tiarantika *et al.*, 2024)**. A constraint at the location is the limited availability of rental facilities for tourism equipment (snorkeling and diving), which must be prepared by the tourists themselves. Therefore, adequate and secure rental services are needed. Similarly, the availability of public toilets and places of worship are key factors in boosting visitor numbers. Efforts to increase tourist interest can be made by providing public transportation routes from Juanda Airport or Bungurasih to the Gili Genting tourist site.

CONCLUSION

The underwater photo transect method was found to be more effective in estimating the percentage of coral cover across different lifeforms. Using this method, the condition of live coral cover in all surveyed locations was evaluated and categorized as good to very good, with Acropora branching identified as the dominant coral type. Water quality also met the required standards for tourism activities. From an ecological perspective, the dimension was classified as moderately sustainable, ranking second after the infrastructure dimension. However, in terms of overall multidimensional sustainability, tourism management on Gili Genting Island, Kabupaten Sumenep, is considered moderately sustainable. To improve sustainability, efforts should focus on the economic, legal, and institutional dimensions. Recommended actions include implementing community training programs for tour guiding, promoting the island, involving local residents in monitoring and supervision of fishery resource use, and enhancing public education and awareness initiatives. These steps will support more sustainable tourism management in the future.

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REFERENCES

Andronicus, A.; Fredinan, Y. and Ahmad, F. (2016)**.** Sustainability Study Of Ecotourism Management Based On Marine Protected Area (MPA) On The Coast Of Bahoi Village, North Minahasa, North Sulawesi**.** J. of Engineering & Manage in Industrial Sys., 4(1): 1-6

Alder, J.; Pitcher, J.; Preikshot, D.; Kaschner, K. and Ferriss, B. (2000). How good is good?. A Rapid Appraisal Technique for Evaluation of the Sustainability Status of Fisheries of the North Atlantic, in: Fisheries Centre, University of British Columbia, Vancouver, pp. 136-178.

Alvi, N.N.; Nurhasanah, I.S. and Persada, C. (2018). Evaluation of the Sustainability of Marine Tourism on Pahawang Island, Pesawaran Regency. Plano Madani : J. of Urban and Regional Plan., 7(1): 59–68. [Indonesian]

Assyifa, R.S., Gatot Y. and Ferdinan Y. (2023). Assessment of Coral Reef Conditions on Genteng Besar and Kayu Angin Genteng Islands, Seribu Islands. J. of Fisheries and Marine Techn., 14 (2): 113-123 [Indonesian]

Azizah, M.N.L.; Wulandari, D. and Marianti, A. (2021). Challenges in Realizing Sustainable River Ecotourism to Improve Human Welfare and Protect Biodiversity in Indonesia. Indonesian J. of Conserv., 10(2), 72–77 [Indonesian]

Balumpapung, J.; Roeroe, K.A.; Paruntu, C.P.; Kusen, J.D.; Wagey, B.T. and Wantesan, **A.S.** (2022). Status of coral reefs at Malalayang Beach, Manado City, North Sulawesi. J. of the Coastal and Tropical Sea., 10 (1): 31-37

Chappell, J. (1980). Coral Morphology, Diversity & Reef Growth. Nature 286:249- 252.

Davis, D. and Tisdell, C. (1996)**.** Economic Management of Recreational SCUBA Diving and the Environment. J. of Environ. Manage., 48:229-248.

Deely, J.; Hynes, S. and Cawley, M. (2022) Overseas visitor demand for marine and coastal tourism. Marine Policy. 143:105176

Erwina, Y.; Kurnia, R. and Yonvitner. (2015). Sustainability Status of Fisheries Resources in Bengkulu Waters. J. of Marine and Fisheries Socioecono., 10(1):21–34.

Farid, A.; Rahma, D.N.U.; Apri. A. and Darmawan, S. (2024)**.** Sustainable Fisheries Management of Flying Fish (Decapterus spp.) with Rapfish Analysis in Pasongsongan Waters, East Java, Indonesia. Egypt Aquat. Biol. Fish., 28(3): 151 – 165

Fauzi, A. and Anna, S. (2002). Evaluation of the Sustainability Status of Fisheries Development: Application of the Rapfish Approach (Case of Coastal Waters of DKI Jakarta). Coast & Ocean. 4(3):43-55

Fauzi, A. (2019). Sustainability Analysis Techniques. Jakarta, Gramedia Pustaka Utama, 312pp. [Indonesian]

Folpp, H.; Lowry, M.; Gregson, M. and Suthers, I.M. (2011). Colonization and community development of fish assemblages associated with estuarine artificial reefs. Brazilian J. of Oceano., 59: 55–67

Folpp, H.R.; Hayden, T.S.; Graeme, F.C.; Michael, B.L.; Ben, M.; Marcus, G. and Suthers, M. (2020). Artificial reefs increase fish abundance in habitat-limited estuaries. J. of Appl. Ecol., 57(9):1752–1761

Ghallab, A.; Mahdy, A.; Madkour, H. and Osman, A. (2020). Distribution and diversity of living natural resources from the most Northern Red Sea Islands, Egypt: I-Hard and Soft Corals. Egypt Aquat. Biol. Fish., 24(5): 124-145.

Gier, L.; Christie, P. and Amolo, R. (2017). Community perceptions of scuba drive tourism development in Bien Unido, Bohol Island, Philippines. J. of Coastal Conserv., 21:153– 166

Giyanto. (2013). Underwater Photo Transect Method for Coral Reef Condition Assessment. Ocean, 38 (1): 47-61 [Indonesian]

Gomez, E.D. and Yap, H.T. (1988). Monitoring reef condition In: Kenchington, R.A. and Brydget ET. Hudson (eds.). Coral Reef Management Hand Book. Unesco Regional Office for South East Asia, Jakarta, pp. 171-178.

Good, N; Schafer, J.B.; Konstan, J.A.; Borchers, A.; Sarwar, B. and Herlocker, **J.** (2000). Combining collaborative filtering with personal agents for better recommendations, Artif. Intell., 35 (4) 439–446.

Herawati, E.Y.; Arsad, S.; Khasanah, R.I.; Yudatomo.; Juniarsa, E.F.; Ma'arif, M.C.; Nugraha, D.R.W.; Aisyah, A.D and Sofarini, D. (2023). Growth rate and survival rate of montipora coral transplant on faba material in Baluran National Park. IOP Conf. Ser.: Earth Environ. Sci., 1273 012068.

Hermawan, M.; Sondita, M.F.A. and Fauzi, A. (2006). Sustainability Status of Small-Scale Capture Fisheries. Bulletin PSP, 15(2):1–19 [Indonesian]

Hershman, MJ.; Good, J.W.; Bernd-Cohen, T.; Goodwin, R.F.; Lee, V. and Pogue, P. (2000) The effectiveness of coastal zone management in the United States, Coast. Manag., 27 (23) 113–138**.**

Idris, I.H.; Narawida, T.; Agustin, R.D.; Oktaviani, D. and Hidayat, M.B. (2023). RAPFISH Analysis in the Study of Sustainability of Development of the Kajoetangan Heritage Tourism Area in Malang City. Brawijaya J. Soc. Sci., 2(2): 115–129 [Indonesian]

Ismane, M.A; Kusmana, C.; Gunawan, A.; Affandi, R. and Suwardi, S. (2018). Sustainability of Turtle Conservation Area Management in Pangumbahan Beach, Sukabumi, West Java. J. of Natural Resources and Enviro. Manag., 8(1):36-43 [Indonesian]

Kavanagh. P.(2001). Rapid Appraisal of Fisheries (RAPFISH) Project. Fisheries Centre, University of British Columbia, 60pp.

Kohler, K.E. and Gill, S.M. (2006). Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. Computer and Geosci., 32 (9): 1259-1269

Karen, L.N.; Tracy, A.Z.; Margaret, P.; Mark, H.; Chesson, OB.; Maria, W. and Daniel, R. (2021). Enhancing artificial reef fish populations by providing invertebrate prey refugia. Fish. Res, 241.

Manuputty. AEW and Djuwariah. (2009). Guide to the Point Intercept Transect (PIT) Method for Baseline Study Communities and Coral Health Monitoring in Marine Protected Area (MPA). COREMAP II -LIPI, Jakarta, 30pp. [Indonesian]

Myers. R. and Raymundo, L.J. (2009) Coral disease in Micronesian reefs: a link between diseaseprevalence and host abundance. Diseases of Aqua. Organ., 87:97-104

Morais. R.A. and Bellwood. D.R. (2020). Principles for estimating fish productivity on coral reefs. Coral Reefs 39 (5):1221-1231

Munandar, E., Adi S., Hery S.N., Hendrawan S., Asep H., Muta A.K., Weksi B., Eren P.F. and Inge Y.D. (2023). Dynamics of Coral Reef Conditions Before and After the Sunda Strait Tsunami on Badul Island. J. of Fisheries and Mar., 12(2): 221-229

Nybakken. J.W. (2007). Marine Biology : an ecological approach. Harper & Row, Publ., New York. 446pp.

Pitcher, T.J. and Preikshot, D. (2001). RAPFISH: A rapid appraisal technique to evaluate the sustainability status of fisheries. Fish. Researc., 49(3):255–270

Rosyidah, U.; Hanifah, L. and Suaibah. L. (2021). Strategy for Developing the Nine Islands of Gili Genting Sumenep Beach as an Icon of Halal Tourism in Madura. J. Ilm. Hosp., 10(2): 6-12 [Indonesian]

Sala, R.; Kabera, Y. and Rumereb. V. (2011). Destructive fishing in COREMAP II area, Raja Ampat. J. of Indonesian Coral Reefs, 30-40

Silvia, D. and Muhsoni, F.F. (2024). Analysis of the Status of Ecotourism Management on Gili Labak Island, Sumenep Using the Rapfish Method. J. of Marine Research. 13(3) : 397-406 [Indonesian]

Suharsono and Sumadhiharga,O.K. (2014). Coral Reef Health Monitoring Guidelines; Coral Reefs, Coral Fish, Megabenthos and Report Writing. Coremap CTI, Indonesian Institute of Science, 372pp [Indonesian]

Van Woesik, R. (2002). Coral Communities and reef Growth in The Southern Great Barrier Reef. Coral Reef Report, Florida, 30pp.

Reza, A.A.; Cahyaningrum, D.C. and Hastuti, S.P. (2021). Analysis of the Sustainability Status of Senjoyo Spring Water Source in the Ecological Dimension with the Method RAP-WARES (Rapid Appraissal for Water Resources). J. Ilmu Lingk., 19(3): 588–598. [Indonesian]

Supriharyono. (2007). Management of coral reef ecosystems. Djambatan, 120pp. [Indonesian]

Tiarantika, R.; Soemarno, S.; Efani, A. and Koderi. (2024). Exploring the Sustainable Status of Community-Based Ecotourism in East Java, Indonesia: A Comprehensive Assessment. Egypt. Aquat. Biol. Fish., 28(3): 585–607.

Triyanto, T.; Affandi, R.; Kamal, M.M. and Haryani, G.S. (2021)**.** Rapfish Analysis in the Formulation of Glass Eel (Anguilla spp.) Fishing Management Policy in the Cimandiri River Estuary, West Java. Agricultural and Environmental Policy Brief Formulation of Strategic Studies. 8(2): 97–107. [Indonesian]

Ustadi, M.I. and Syarifudin, T.P. (2022). Analysis of Underwater Tourism Destination Development Factors on Gili Genting Island, Sumenep Using the Analytical Hierarchy Process Method. J. Apl. Teknol. Inf. Manaj., 3(2): 158–164 [Indonesian]

Wahyudi, A.; Ayu, D.; Rini, S. and Muhsoni, F.F. 2023. Analysis of the Aesthetic Value of Gili Labak Island Sumenep Regency with the Scenic Beauty Estimation (SBE) Method. J. Mar. Res., 12(3): 465–473. [Indonesian]

Wilson, S.K.; Graham, N.A.J.; Prachett, M.S.; Jones, G.P. and Polunin, N.V.C. (2006). Multiple Disturbances and the Global Degradation of Coral Reefs: Are Reef Fishes at Risk or Resilient? J. of Global Change Bio.,12:2220-2234

Yasir-Haya, L.O.M. and Masahiko Fujii. (2020). Assessment of coral reef ecosystem status in the Pangkajene and Kepulauan Regency, Spermonde Archipelago, Indonesia, using the rapid appraisal for fisheries and the analytic hierarchy process. Marine Policy. 118:1-18

Yunandar, Y. (2011). Mapping of Fringing Reef Conditions and Water Quality of Angsana Beach, South Kalimantan. Bumi Lestari, 11(1) : 50-57 [Indonesian]

Zamani, P.N.; Wardiatno, Y. and Nggajo, R. (2011). Development Strategy for Management of Yellowtail Fish Resources (Caesio cuning) in Coral Reef Ecosystems in the Seribu Islands. J. of Fish. Sci. and Tech., 6(2):38-51[Indonesian]