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Sustainability Status of Gillnet Capture Fisheries Based on Economic, Ecological, Technological, Institutional, and Social Aspects in Panipahan Pasir Limau Kapas Sub-District Rokan Hilir District

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Abstract

Rokan Hilir Regency, particularly Pasir Limau Kapas District, has significant potential for capture fisheries. However, ecosystem sustainability depends on high-value fish resources such as senangin and mackerel. Therefore, a sustainable study of fisheries management is needed based on ecological, socioeconomic, community, and institutional dimensions to ensure the sustainable use of fish resources. This research evaluates the sustainability status of gill net capture fisheries in Panipahan, Pasir Limau Kapas District, Rokan Hilir Regency, based on five dimensions: economic, ecological, technological, institutional, and social. The analysis method used is Rapid Appraisal for Fisheries (RAPFISH) with a Multidimensional Scaling (MDS) approach. The results show that the institutional dimension had the highest sustainability index at 92.08%, classified as "sustainable", while the technological dimension had the lowest index at 39.87%, indicating a "less sustainable" status. The economic and social dimensions scored 53.11% and 57.75% respectively, categorised as "moderately sustainable", whereas the ecological dimension scored 43.96%, also "less sustainable". These findings indicate that gill net capture fisheries in Panipahan are not yet fully sustainable, particularly regarding technology and ecology. Therefore, there is a need to enhance environmentally friendly fishing gear use, strengthen local institutional regulations, and increase public education and community involvement to support sustainable fisheries resource management.

1. INTRODUCTION

Pasir Limau Kapas has great potential for capture fisheries, primarily due to its location on the coast of the Malacca Strait. The marine capture production in Rokan Hilir Regency in 2017 reached 36,858.15 tons, with Pasir Limau Kapas contributing approximately 54.62% of the total output, or 20,132.88 tons. However, this production experienced a significant decline compared to the previous year (BPS Rokan Hilir, 2017).

Several factors contribute to the decline in capture fisheries production in this region, including rising production costs, unprofitable selling prices, reduced fishing frequency, adverse weather, and shifting fishing grounds. Additionally, one of the causes of declining catch results is the use of non-selective fishing gear. In Panipahan, non-selective fishing gears such as *sondong* (push nets), *bubu tiang* (stake traps), and trawl nets are still used. These three types of fishing gear catch a wide range of fish sizes from small to large and can damage the marine ecosystem. The presence of these fishing gears poses a threat to the sustainability of gill net fisheries.

2. RESEARCH METHODS

Time and Place

This research was conducted in April–May 2024. The research location is Panipahan, Pasir Limau Kapas Sub-district, Rokan Hilir Regency.

Material and Method

The tools used in this research include a mobile phone camera, measuring tape, writing instruments, and a laptop to record important information during the study. The materials used consist of questions or questionnaires for respondent interviews. The research objects are fishers in Panipahan, Pasir Limau Kapas Sub-district, Rokan Hilir Regency. The data collected in this study consists of primary and secondary data, both quantitative and qualitative. According to Sekaran & Bougie (2016), primary data is information obtained directly by the researcher related to the study's specific objectives. Meanwhile, secondary data is obtained or collected by someone conducting research from existing sources.

Table 1. The range of sustainability index values is classified into four categories

Index Value	Sustainability Index Range	Sustainability Status
0 – 25	Poor	Not Sustainable
26 – 50	Low	Less Sustainable
51 – 75	Moderate	Moderately Sustainable
76 - 100	Good	Sustainable

3. RESULTS AND DISCUSSION

Economic Dimension Sustainability Analysis

The economic dimension in this study focuses on aspects such as the profitability of fishing operations, the contribution of fisheries to the Gross Regional Domestic Product (GRDP), per capita income, ownership of fishing gear, subsidy levels, employment and income alternatives, market orientation, average crew income relative to the provincial minimum wage, fisher income relative to working hours, profit transfer between fishers and local/external economic actors, and employment absorption. The scoring results for each economic attribute based on analysis and gathered information are shown in Table 2.

Table 2. Scoring Results of Economic Attributes

No	Attribute	Score
1.	Profitability of fishing operations	4
2.	Fisheries contribution to PDRB	1
3.	Per capita income	2
4.	Ownership (benefits received by gear owners)	1
5.	Subsidy level for fisheries	1
6.	Employment and income alternatives	1
7.	Market orientation or destination	1
8.	Average crew income relative to minimum wage	1
9.	Fisher's income relative to working hours	1
10.	Profit transfer between local and external economic actors	1

The scores in the economic dimension (as shown in Table 2) were derived from each respondent's mode values and analysed using the RAPFISH method. Two attributes received the highest mode scores: fishing operation profit and per capita income. The lowest mode scores appeared in eight attributes, including GRDP contribution, ownership, subsidies, employment alternatives, market orientation, relative crew income, fisher income relative to working time, and profit transfer. The scoring analysis processed via the RAPFISH method is presented in Figure 1. The RAPFISH analysis indicates that the economic dimension scored a sustainability index of 53.11%, which falls under the category of moderately sustainable (Figure 2).

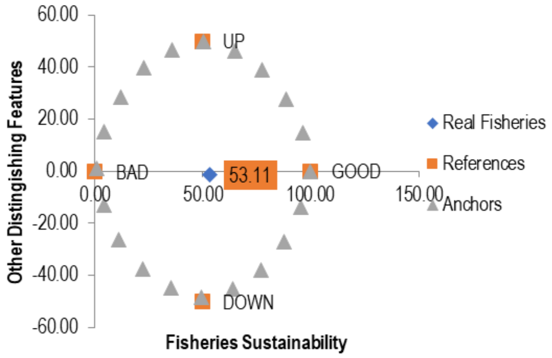

Figure 1. RAPFISH analysis result of the economic dimension

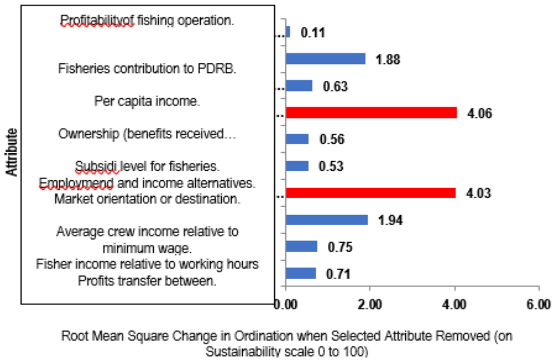

Figure 2. Leverage analysis of economic attributes

The leverage analysis identifies two sensitive attributes in the economic dimension: market orientation (RMS = 4.06%) and ownership/benefit distribution (RMS = 4.03%). Ownership of fishing facilities relates directly to profit distribution and reflects the local population's independence in managing fishery assets without reliance on external parties (Nababan et al., 2008).

Table 3. RAPFISH statistical results of the economic dimension

	Index	Status
Economic Aspect	53,11%; *Stress*: 0,13; R^2: 0,94	Moderately Sustainable

A stress value of 0.13 indicates a close match between the model and actual conditions; the smaller the stress value, the more accurate the model.

Ecological Dimension Sustainability Analysis.

The ecological dimension in this study focuses on attributes such as the level of water exploitation, discards and bycatch, reduction in fishing area, changes in fish species over the past five years, changes in fish size over the past five years, and the utilization rate of water areas. The scoring results of each ecological attribute based on the analysis and data collected during the research are presented in Table 4.

Table 4. Scoring results of ecological attributes

No	Attribute	Score
1.	Level of fisheries exploitation	3
2.	Discard and bycatch	1
3.	Reduction in the fishing area	1
4.	Changes in fish species over the past five years	1
5.	Changes in fish size over the past five years	2
6.	Utilisation of water areas	1

The scores for the ecological dimension were derived from the mode of all respondent scores, then tabulated using Microsoft Excel. One attribute with the highest mode score was the level of fisheries exploitation (score 3), and the change in fish size in the past five years scored 2. Attributes such as fishing area reduction, fish species change, and water utilisation level scored 1. The lowest score of 0 was found in the fisheries exploitation level. The RAPFISH analysis results of the ecological dimension are shown in Figure 3.

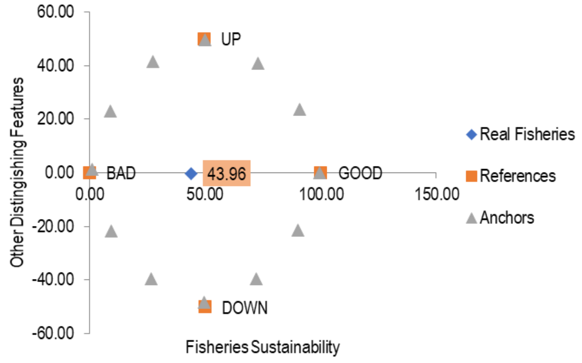

Figure 3. RAPFISH analysis result of the ecological dimension

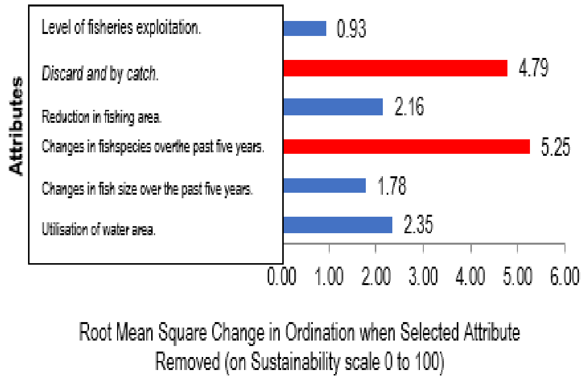

Figure 4. Leverage analysis of ecological attributes

RAPFISH also provides leverage analysis results, identifying the most sensitive variables (attributes that act as sustainability). The Root Mean Square (RMS) value represents the contribution of each attribute to sustainability. Higher values indicate greater influence (Yusuf et al., 2021). The leverage analysis identified two sensitive ecological attributes: Fish size has changed over the past five years (RMS = 4.79%). This attribute is a critical indicator, as decreasing fish size suggests a reduction in fish stock (Nababan et al., 2008). Reduction in fishing area (RMS = 5.25%). This attribute suggests a lack of decrease in fish populations across large geographic regions, indicating a healthy ecosystem (Abdullah et al., 2011).

Table 5. RAPFISH statistical results of the ecological dimension

	Index	Status
Ecological Aspect	43,96%; *Stress*: 0,15; R^2 : 0,93	Less Sustainable

A stress value of 0.15 indicates that the model closely resembles real conditions. The lower the stress value, the less distortion occurs in the model. Conversely, the closer the stress value is to 1, the more distortion exists. With an R^2 above 80%, the sustainability index results are considered valid.

Technological Dimension Sustainability Analysis

The technological dimension in this study focuses on seven attributes: fish landing sites, fishing trip duration, type/characteristics of fishing gear, gear selectivity, use of fishing aids, vessel size, and post-harvest handling. The scoring results of each technological attribute based on the collected data and information are presented in Table 6.

The scores for the technological dimension were derived from the mode of all respondent scores and tabulated using Microsoft Excel. Attributes with the highest mode score (2) include fishing trip duration, use of fishing aids, and vessel size. Meanwhile, attributes such as fish landing site, type/characteristics of gear, gear selectivity, and post-harvest handling received lower mode scores of 1. The RAPFISH analysis result for the technological dimension is shown in Figure 5.

The leverage analysis of the technological dimension identifies four sensitive attributes: Size of fishing vessel (RMS = 4.56%); Gear selectivity (RMS = 3.84%); Type/characteristics of fishing gear (RMS = 3.78%); Fishing trip duration (RMS = 4.56%)

Table 6. Scoring results of technological attributes

No	Attribute	Score
1	Fish landing site	1
2	Duration of the fishing trip	2
3	Type and characteristics of gear	1
4	Selectivity of fishing gear	1
5	Use of fishing aids	2
6	Size of the fishing vessel	2
7	Post-harvest handling	1

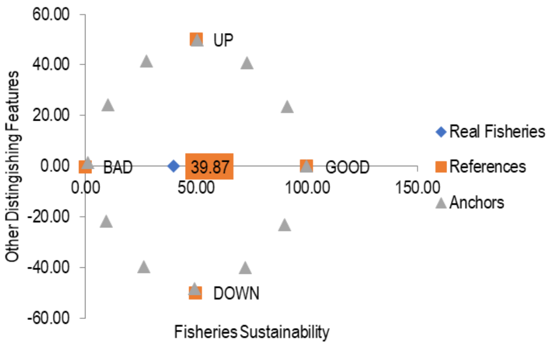

Figure 5. RAPFISH analysis result of the technological dimension

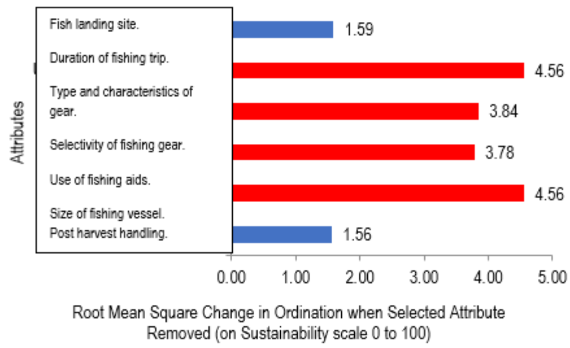

Figure 6. Leverage analysis of technological attributes

Table 7. RAPFISH statistical results of the technological dimension

	Index	Status
Technological Aspect	39,87%; *Stress*: 0,15; R^2: 0,93	Less Sustainable

Institutional Dimension Sustainability Analysis

The institutional dimension in this study focuses on seven attributes: availability of formal fisheries management regulations, availability of informal fisheries management regulations, availability of law enforcement personnel or local supervisory agencies, democratic decision-making processes, the role of formal institutions supporting fisheries resource management, the availability and role of local community leaders, and the role of regional institutions supporting fisheries resource management. The scoring results for each institutional attribute based on data and information are presented in Table 8.

Table 8. Scoring results of institutional attributes

No	Atribut	Skor
1	Availability of formal fisheries management regulations	1
2	Availability of informal fisheries management regulations	1
3	Availability of law enforcement personnel or local supervisory agencies	2
4	Democratic decision-making processes	2
5	Role of formal institutions supporting fisheries resource management	1
6	Availability and role of local community leaders	2
7	Role of local institutions supporting fisheries resource management	2

The scores in the institutional dimension, as shown in Table 8, were obtained from the mode of respondent scores and tabulated using Microsoft Excel. Based on the RAPFISH analysis results (Figure 8), the sustainability index of the institutional aspect for stake trap fisheries is 92.08%, which falls within the 75–100% range.

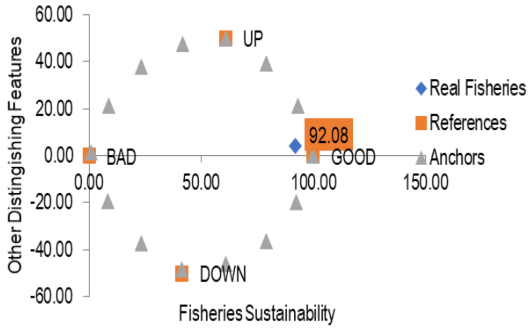

Figure 7. RAPFISH analysis result of the institutional dimension

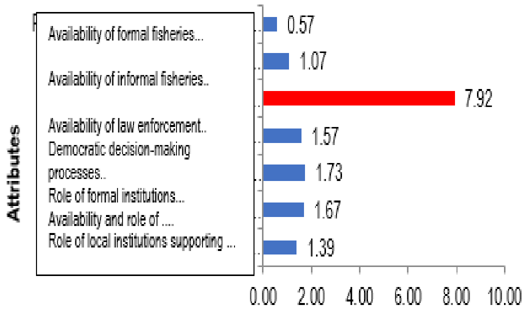

Figure 8. Leverage analysis of institutional attributes

The leverage analysis of the institutional aspect shows one sensitive attribute: The role of formal institutions (e.g., Fisheries Department, HNSI). The role of formal institutions (e.g., Fisheries Department, HNSI) in supporting fisheries resource management (RMS = 7.92%). Informal regulations in fisheries management also play a substantial and essential role, as they help raise awareness among local communities and fishers. Informal norms or agreements can effectively regulate fisher behaviour through social control mechanisms.

Table 9. RAPFISH statistical results of the institutional dimension

	Index	Status
Institutional Aspect	92,08%; *Stress*: 0,13; R^2: 0,94	Sustainable

According to Table 9, the stress value of the institutional dimension is 0.13. A lower stress value indicates a stronger match between the model and actual conditions.

Social Dimension Sustainability Analysis

The social dimension in this study focuses on six attributes, namely: knowledge of the aquatic environment, fishers' education level, status and frequency of conflicts, family participation in the utilisation of fishery resources, frequency of community meetings related to fisheries resource management, and frequency of extension and training for fishers. The scoring results for each social attribute based on data and information are presented in Table 10.

Table 10. Scoring results of social attributes

No	Attribute	Score
1	Knowledge of the aquatic environment	1
2	Fishers' education level	0
3	Status and frequency of conflicts	1
4	Family participation in the utilisation of fishery resources	1
5	Frequency of community meetings related to fisheries resource management	2
6	Frequency of extension and training for fishers	1

The scores in the social dimension, as listed in Table 10, were obtained from the mode values of all respondent scores and then tabulated using Microsoft Excel. The frequency of community meetings related to fisheries resource management had the highest value of 2, indicating that all residents of Panipahan are involved in fisheries resource management. In the social dimension, there are four attributes with a score of 1: knowledge of the aquatic environment, status and frequency of conflicts, family participation in utilizing fishery resources, and frequency of extension and training for fishers. Meanwhile, the lowest score was found in one attribute, namely the fishers' education level, which is very low. Based on the RAPFISH analysis results, the sustainability index of the social aspect of stake trap fisheries (Figure 10) showed a value of 57.75%, within the range of 50 to 75. According to the sustainability index classification proposed by Budianto in Fitriani et al. (2014), the social aspect falls into the "moderately sustainable" category.

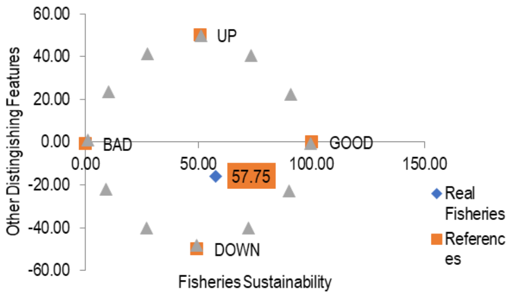

Figure 9. RAPFISH analysis result of the social dimension

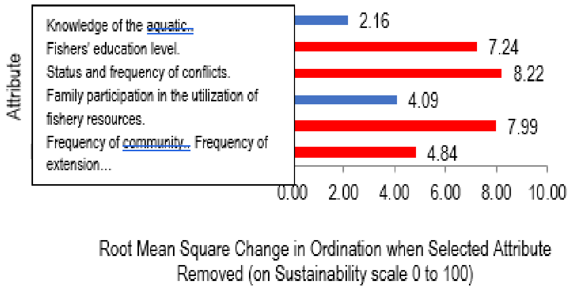

Figure 10. Leverage analysis of social attributes

The leverage analysis results of the social aspect indicate that there are four leverage attributes: Frequency of community meetings related to fisheries resource management (RMS = 7.24%); the lack of meetings among residents in Panipahan regarding fisheries management often causes problems in the implementation and effectiveness of conservation policies. This can lead to non-compliance with regulations and reduced success of conservation programs. According to Pomeroy et al. (2001) in the article "Fisheries Co-Management: A Comparative Analysis", community involvement in regular meetings related to fisheries management significantly increases management success and compliance with regulations.

Family participation in the utilisation of fishery resources (RMS = 8.22%); the lack of family participation in the utilisation of fishery resources results in families not understanding what fisheries resource utilisation means due to minimal socialisation from the government regarding fisheries' resource management. Fishers' education level (RMS = 7.99%); the education level of fishers is very important to ensure the sustainability of fish resources and ecosystems, as the higher the education level, the better their understanding and ability to manage fishery resources. The education level of the community in Panipahan is very low. Knowledge of the fisheries environment (RMS = 4.84%) is very important to ensure the sustainability of fish resources and ecosystems. This knowledge also depends on the education level, as the higher a person's education, the better their understanding and ability to manage fishery resources. The education level of the community in Panipahan is very low (Supriadi et al., 2016).

Table 11. Statistical values of the social aspect of the RAP analysis

	Index	Status
Social Aspect	57,75%; Stress: 0,14; R^2 : 0,93	Moderately Sustainable

Based on Table 11, the stress value obtained for the social aspect is 0.14. The smaller the stress value, the closer the data relationship to the actual condition.

Sustainability Status of Gillnet Capture Fisheries Based on Multidimensional Analysis

Based on the research results and data processing, the sustainability index values of gillnet capture fisheries in Panipahan were obtained as shown in Figure 11.

From Figure 11, it can be seen that the highest sustainability index is the institutional aspect, with an index value of 92.08% at the same time, the lowest is the technological aspect, with an index value of 39.87%. The statistical parameters from the RAP analysis using the MDS method serve to determine the accuracy of the study results conducted at the research location. The analysis results show stress and R^2 (coefficient of determination) values for each aspect. These determine whether additional attributes are needed to accurately reflect the studied elements (close to actual conditions). The statistical parameters (stress and R^2 values) of the multidimensional RAP analysis of stake trap fisheries and each aspect are presented in Table 12.

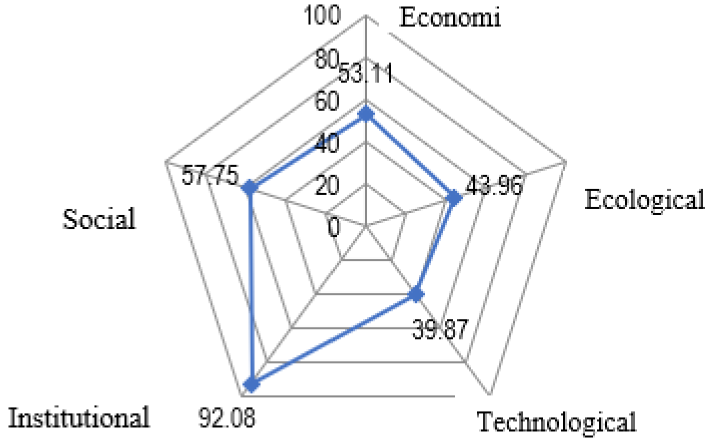

Figure 11. Kite diagram of multidimensional sustainability index

Table 12. Statistical parameters (goodness of fit) of RAP analysis results

Statistical Parameter (1)	Ecological Aspect (2)	Economic Aspect (3)	Technological Aspect (4)	Institutional Aspect (5)	Social Aspect (6)
Stress Value	0,15	0,13	0,15	0,13	0,14
R^2	0,93	0,94	0,93	0,94	0,93

Based on Table 12, the stress values from the RAPFISH analysis of each aspect are all below 20%, indicating good attribute accuracy (goodness of fit). Meanwhile, the R^2 values for each aspect are quite high (close to 1). Thus, these two statistical parameters indicate that all attributes have been used sufficiently well to explain the sustainability of gillnet capture fisheries at the research location.

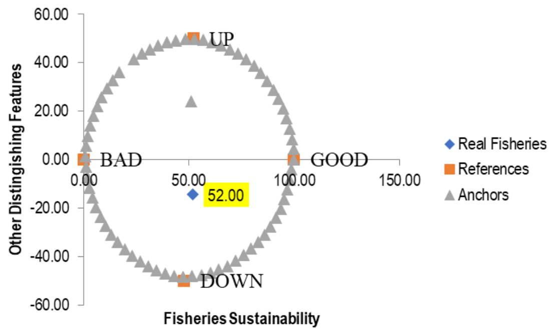

Figure 12. Multidimensional analysis of sustainability assessment results

The multidimensional sustainability analysis of gillnet capture fisheries resulted in an index of 52%, which falls into the "moderately sustainable" category. This index is based on 35 attributes covering five main aspects: ecological, economic, technological, social, and institutional.

Table 13. Statistical values of multidimensional analysis

	Index	Status
Social Aspect	52%; *Stress*: 0,12; R^2 : 0,95	Moderately Sustainable

Based on Table 13, the stress value obtained from the multidimensional analysis is 0.12%. The smaller the stress value, the closer the data relationship to the actual condition. A < 20% value indicates good attribute accuracy (goodness of fit). Meanwhile, the multidimensional R^2 value is quite high (close to 1). Thus, these two statistical parameters indicate that all attributes have been used sufficiently well to explain the sustainability of gillnet capture fisheries at the research location.

4. CONCLUSIONS

The sustainability status of small-scale fisheries using gillnet in Panipahan, Pasir Limau Kapas Sub-district, Rokan Hilir Regency, shows that the institutional aspect is sustainable with an index value of 92.08%. In comparison, the social and economic aspects are moderately sustainable with index values of 57.75% and 53.11%, respectively. Meanwhile, the ecological and technological aspects, with index values of 43.96% and 39.87% respectively, are categorized as less sustainable.

Optimal management efforts for capture fisheries must be immediately carried out by recording the landed fish and the efforts undertaken to prevent overexploitation, which could ultimately harm all parties. In addition, there is a need to develop conservation efforts through local institutions so that exploitation activities can be balanced with conservation activities to reduce the impact on fishery resources in the long term. There is also a need for studies on the stock status of economically important fish species in this area to complement the basis for making policies for sustainable capture fisheries management in the region.

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