Sustainable index of giant tiger prawn (*Penaeus monodon*) in Rokan Hilir Regency, Riau Province

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Abstract. Rokan Hilir Regency is a strategically important coastal region for the development of fisheries and marine resources. Sustainable management of capture fisheries is essential for supporting fishing communities, advancing national interests, and achieving broader sustainable development goals, including meeting diverse consumption needs. This research aimed to evaluate the sustainability status and identify leverage factors that supported the sustainability of giant tiger prawn (*Penaeus monodon*) resources in Rokan Hilir Regency. The study used a survey method, utilizing structured interviews to gather data on ecological, economic, social, institutional, and technological aspects. A multidimensional scaling (MDS) approach, utilizing the Rapfish technique, indicates that giant tiger prawn are less sustainable, with the following sustainability indices: social (55.70), institutional (52.88), ecological (47.76), economic (46.70), and technological (46.48). Key leverage factors for enhancing sustainability include the range of fishing areas, labor absorption, socialization in fishing practices, gear selectivity, fishing aids, and democratic policymaking processes.

1 Introduction

Capture fisheries play a vital role in fulfilling global food requirements [1]. The utilization of fisheries resources in Indonesia, particularly in marine capture fisheries, is predominantly characterized by small-scale artisanal operations [2]. These fisheries typically exhibit traits such as limited operational scale, basic technology, restricted fishing ranges close to the coast, and relatively low productivity [3]. Capture fisheries is one of the most important economic activities in Rokan Hilir Regency, and its contribution is significant to the overall fisheries production [4]. This situation indicates that the availability of fisheries resources presents an opportunity for economic growth and enhances the welfare of fishing communities [5-6].

Rokan Hilir is one of the regencies in Riau Province. The Rokan Hilir Regency is located within the Malacca Strait territory [7]. Fishing activities in the waters of Rokan Hilir are quite active, as this region serves as a vital link between Rokan Hilir, its neighboring areas, and

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foreign countries [8]. The establishment of sea transportation access has enabled Rokan Hilir Regency to significantly boost fishing activities in the area. Department of Fisheries Rokan Hilir Regency reported that marine fisheries production from 2021 to 2023 exhibited an upward trend, with 51,103.96 tons in 2021, 51,610.15 tons in 2022, and 52,006.44 tons in 2023. This production includes a variety of fish and prawn species.

One type of prawn found in the waters of Rokan Hilir Regency is *Penaeus monodon*, commonly known as the giant tiger prawn. This species is characterized by its tiger-like coloration and is larger in size compared to other prawns [9]. Based on data from the Department of Fisheries Rokan Hilir Regency, the production of giant tiger prawn was 126,211 kg in 2021, 148,579 kg in 2022, and 437,267 kg in 2023. The increase in production raises concerns about the efficiency and sustainability of fisheries. The rapid annual rise in catch yields may lead to significant problems in the future [10]. Excessive and unsustainable capture practices can threaten the sustainability of the giant tiger prawn population and disrupt the marine ecosystem as a whole. Effective management strategies are essential for the responsible utilization of fisheries resources [11-12].

The management of fishery resource potential must be planned and controlled to optimize its utilization, thereby enhancing the welfare of the community both now and in the future [13-15]. Sustainable fisheries management is currently a significant concern for stakeholders, aimed at ensuring the long-term sustainability of fishery resources in Rokan Hilir Regency. Sustainability necessitates a comprehensive understanding that integrates ecological, social, economic, and institutional dimensions [16-17]. To support the sustainable management of giant tiger prawn fisheries, a variety of information is essential to achieve the goal of sustainability. This information encompasses ecological, economic, social, institutional, and technological aspects. Given this context, research is necessary to assess the management of giant tiger prawn fisheries in Rokan Hilir Regency, focusing on the sustainability index value and the factors influencing sustainability. The objective of this research is to determine the sustainability status of giant tiger prawn in Rokan Hilir Regency by integrating various management aspects to ensure optimal and sustainable practices.

2 Material and methods of research

2.1 Data collection

This research utilizes both primary and secondary data concerning the attributes of sustainability dimensions: ecological, economic, social, institutional, and technological. Primary data were collected through direct field observations and interviews with key stakeholders, including the head of department of fisheries, fisheries extension officers, community leaders, academics, and fishermen, who were selected using a purposive sampling method. Secondary data were sourced from relevant agencies, such as Rokan Hilir Statistics, the Department of Fisheries, and existing research pertinent to this study.

2.2 Data analysis

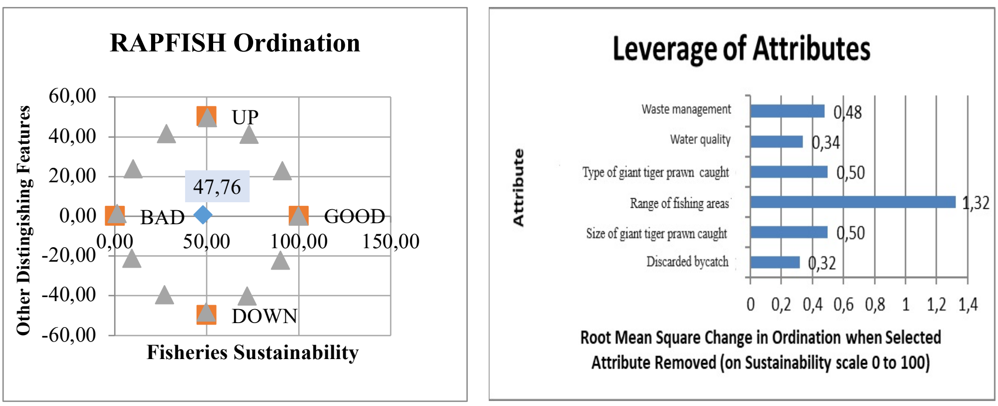
The sustainability analysis of the giant tiger prawn in Rokan Hilir Regency employs the Multidimensional Scaling (MDS) technique in conjunction with the Rapid Appraisal for Fisheries (Rapfish) approach [18-20]. This analysis develops attributes based on a five-dimensional framework, which includes ecological, economic, social, institutional, and technological.

Scores are assigned based on field observations, interviews, questionnaires, and secondary data, utilizing a scale of 1 to 4. A low score indicates the least favorable conditions for sustainable management, while a high score signifies the most favorable conditions for sustainable management [21]. The sustainability index scale ranges from 0 to 100. In this study, four categories of sustainability status are defined: 0-25 (unsustainable), 26-50 (less sustainable), 51-75 (quite sustainable), and 76-100 (sustainable) [22].

3 Results

3.1 Ecological dimension

The ecological aspect is crucial for the management of the giant tiger prawn. The sustainability of giant tiger prawn management is reflected in the community's reliance on this species and its effects on ecological conditions. An analysis conducted using Rapfish software reveals that the sustainability index for the ecological dimension is 47.76, indicating a less sustainable status, as illustrated in Figure 1. This situation negatively impacts the sustainability of giant tiger prawn fishing. If not addressed, it could lead to extinction.



(*a*) (*b*)

Fig.1. (a) Sustainability index of ecological dimension, (b) leverage attributes of ecological dimensions.

There are three sensitive attributes that impact the ecological dimension: range of fishing area (RMS = 1.32), type of giant tiger prawn caught (RMS = 0.50), and size of giant tiger prawn (RMS = 0.50). The identification of these sensitive attributes is based on Pareto analysis [23]. The first sensitive attribute, a range of fishing area, refers to the aquatic zone where fishing gear can be effectively utilized to capture available resources [15]. The increasing distance to the fishing areas indicates that the carrying capacity of the waters in Rokan Hilir Regency is declining. This decline is attributed to various factors, including the ecosystem that supports giant tiger prawns. As a result, fishermen are compelled to travel up to 12 miles to catch them. Additionally, it is crucial to consider the sensitive attributes of the second and third categories, specifically the types and sizes of prawns being caught. The intense harvesting of young giant tiger prawns and those that are spawning can lead to a significant reduction in the natural stock of these prawns [24].

3.2 Economic dimension

The economic dimension refers to the capacity of an activity to effectively utilize capture fisheries resources in a manner that yields long-term economic sustainability and overall sustainability [25]. The activity of capturing giant tiger prawns aims to maximize profits.

Analysis results using the Rapfish software indicate that the sustainability index for the economic dimension is 46.70, which reflects a less sustainable status, as illustrated in Figure 2. Each attribute analyzed within the economic dimension plays both a direct and indirect role in the sustainability level of giant tiger prawns.

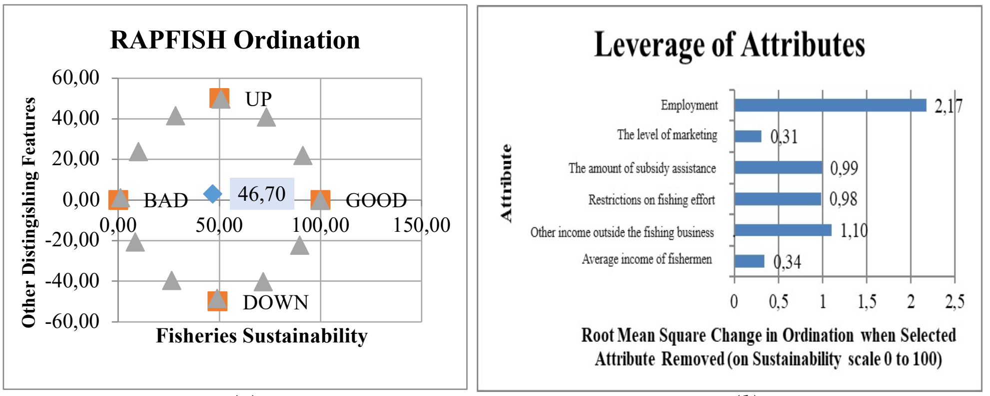


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Fig.2. (a) Sustainability index of economic dimension, (b) leverage attributes of economic dimensions.

There are three sensitive attributes that influence the economic dimension: employment (RMS = 2.17), other income outside the fishing business (RMS = 1.10), and the amount of subsidy assistance (RMS = 0.99). The identification of these sensitive attributes is based on Pareto analysis [23]. First, the employment attribute significantly impacts the average income of the community, as economic institutions affect labor performance, which in turn influences the income of fishermen. According to interviews with fishermen, the development of giant tiger prawn fisheries in Rokan Hilir Regency has not seen an increase. Therefore, it is essential to consider this situation so that unemployed individuals can utilize giant tiger prawns as a potential source of income.

The second sensitive attribute is the other income outside the fishing business, which impacts fishermen's overall earnings. Income from catching giant tiger prawn is often uncertain and unstable. Interviews with fishermen reveal that only a small number engage in additional income-generating activities, either independently or through family members. This indicates that the majority of fishermen in Rokan Hilir Regency rely heavily on fishing as their primary source of income. Consequently, the Department Fisheries of Rokan Hilir Regency has initiated business skills training programs, such as those focused on processing, to enhance the value of giant tiger prawns and improve fishermen's earnings.

The third sensitive attribute is the amount of subsidy assistance. When substantial subsidies are provided, fishermen may excessively exploit marine resources. Conversely, if subsidies are not available, it becomes challenging for fishermen to sustain their fishing efforts. This situation presents significant difficulties. In the short term, fishermen may experience profits, but in the long term, their ability to go to sea diminishes [26]. Therefore, subsidies should not be allocated for the exploitation of fisheries in overexploited waters, instead, they should be directed toward areas with abundant resource stocks. Additionally, if the subsidy levels are reduced, it is essential to improve the pricing structure for shrimp caught by fishermen [27].

3.3 Social dimension

The social dimension describes how the social system within human society, specifically in the context of capture fisheries communities, can or cannot support the long-term and sustainable development of capture fisheries. In Rokan Hilir Regency, the utilization of giant tiger prawns is conducted intensively. Additionally, conflicts among fishermen in this regency are rare, which positively contributes to the sustainability status of the fisheries. Therefore, efforts to strengthen relationships among fishermen—such as maintaining fishermen's groups or forums and implementing the principle of mutual cooperation—are crucial for supporting sustainability. The analysis results obtained using Rapfish software indicate that the sustainability index for the social dimension is 55.70, reflecting a fairly sustainable status, as illustrated in Figure 3.

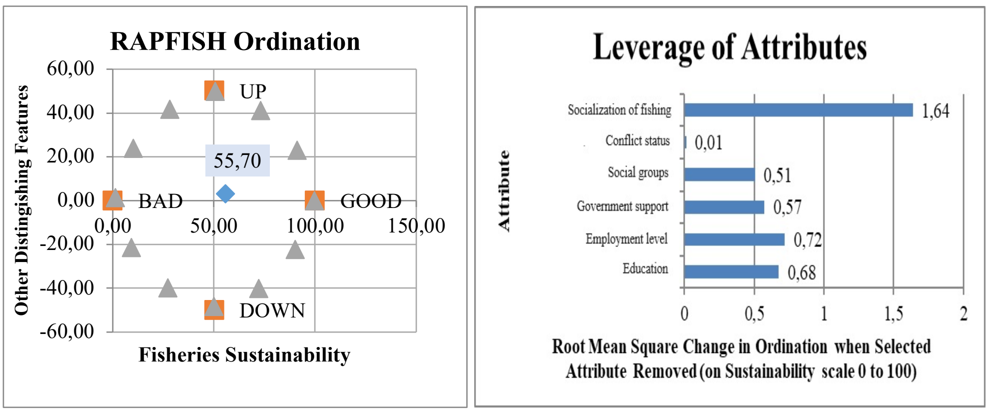

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Fig.3. (a) Sustainability index of social dimension, (b) leverage attributes of social dimensions.

There are three sensitive attributes that impact the social dimension: socialization of fishing (RMS = 1.64), employment level (RMS = 0.72), and education (RMS = 0.68). The identification of these sensitive attributes is based on Pareto analysis [23]. The first sensitive attribute, socialization of fishing, indicates that the relevant agency has not conducted adequate socialization efforts, resulting in fishermen's lack of understanding regarding the capture and preservation of the aquatic environment. This deficiency is evident in the fishermen's limited knowledge about environmental conservation practices. Enhanced socialization is anticipated to improve understanding of the management and conservation of giant tiger prawn at both the community and local government levels [28].

The second sensitive attribute, the sustainability of giant tiger prawn, is significantly influenced by the actions and decisions made at all levels of fishermen's work. The levels of fishermen's expertise are categorized into novice fishermen, experienced fishermen, and owner fishermen. In Rokan Hilir Regency, the majority of fishermen are experienced, having worked in the industry since childhood and adolescence. They inherit fishing skills from generation to generation. If they fail to keep up with the latest developments in sustainable fishing practices, they may resort to overfishing. To prevent this, it is essential for fishermen to adhere to fisheries regulations and implement sustainable fishing techniques [29].

The third sensitive attribute, education, significantly influences the utilization and management patterns of fisheries resources among fishermen. In the research area, the education level of fishermen is relatively low, falling below the national average. This lack of education can lead to a diminished understanding, concern, and sense of responsibility regarding the sustainability of giant tiger prawns [30]. Consequently, it is essential for local government agencies to organize informational education initiatives, such as counseling and training, to enhance fishermen's awareness. By providing knowledge and skills, these programs can help create added value from the utilization of giant tiger prawns, improve their role in resource management, and mitigate harmful practices.

3.4 Institutional dimension

Fishery resource management must incorporate elements of institutional governance, including legal instruments, to ensure that all stakeholders, including natural fishery resources, benefit within a framework of sustainable utilization. Consequently, institutions and laws serve as critical measures of fisheries sustainability. Effective policies can only function optimally when supported by robust legal enforcement. Analysis using the Rapfish software reveals that the sustainability index for the institutional dimension is 52.88, indicating a fairly sustainable status, as illustrated in Figure 4.

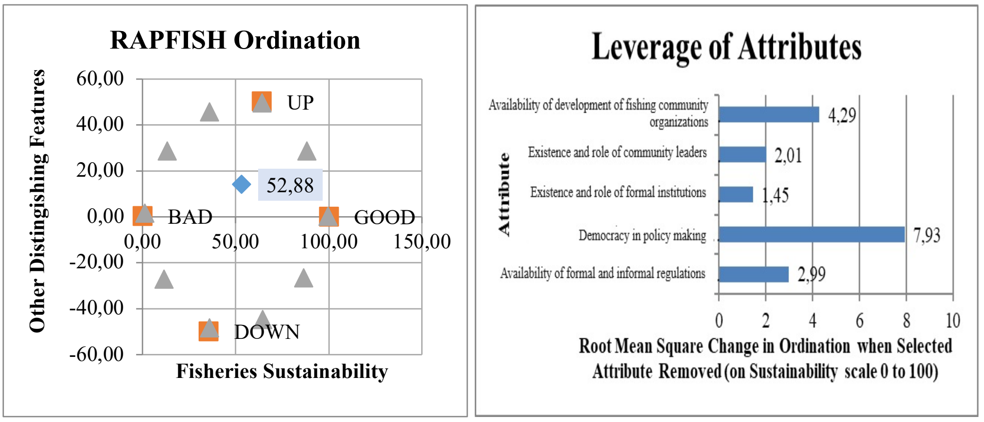

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Fig.4. (a) Sustainability index of instutional dimension, (b) leverage attributes of instutional dimensions.

There are two sensitive attributes that influence the institutional dimension: democracy in policy making (RMS = 7.93) and the availability of development of fishing community organizations (RMS = 4.29). The identification of these sensitive attributes is based on Pareto analysis [23]. The first sensitive attribute, democracy in policy making, refers to a collective decision-making process involving both fishermen and stakeholders [31]. The aim of this approach is to strengthen the existing institutions in the research area. By fostering democratic policy determination, this attribute within the institutional dimension can be enhanced and should be continuously pursued to ensure the sustainable management of giant tiger prawns in Rokan Hilir Regency.

The second sensitive attribute is the availability of development of fishing community organizations, which plays a crucial role in the sustainability of giant tiger prawn harvesting management. This development significantly enhances the welfare of fishermen and serves as a vital means of communication with stakeholders. With organized fishermen's groups, it becomes easier to provide assistance and understand the needs of fishermen engaged in shrimp harvesting activities. Responsive and environmentally conscious fisheries practices can be protected, regulated, and effectively implemented through regular fishermen meetings [32].

3.5 Technological dimension

In the capture fisheries sector, technological applications can illustrate the scale of operations or clusters of capture fisheries, as well as reflect the ethical practices of fisheries operators in utilizing fish resources. Ultimately, inappropriate technological applications can lead to environmental damage and even provoke social conflicts among fishermen. Provisions related to the application of technology in the utilization of fishery resources are extensively outlined in the Code of Conduct for Responsible Fisheries (FAO, 1995). Analysis results using the Rapfish software indicate that the sustainability index for the technology dimension is 46.68, which signifies a less sustainable status, as shown in Figure 5.

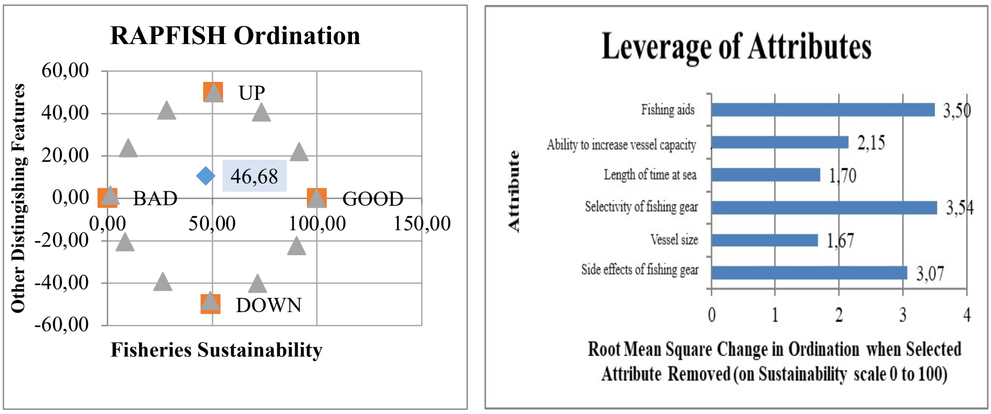

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Fig.5. (a) Sustainability index of technological dimension, (b) leverage attributes of technological dimensions.

There are three sensitive attributes that influence the technological dimension: the selectivity of the fishing gear (RMS = 3.54), fishing aids (RMS = 3.50), and side effects of fishing gear (RMS = 3.07). The identification of these sensitive attributes is based on Pareto analysis [23]. The selectivity of fishing gear is a crucial aspect of the sustainability dimension of technology, as it is directly linked to the performance of capture fisheries. The selectivity of fishing gear involves considerations of the extent, timing, and diversity of catch results [33]. In Rokan Hilir Regency, fishermen commonly use a traditional fishing gear known as to catch giant tiger prawns. The is a cost-effective fishing tool that does not require significant capital investment. The primary catch of the "sondong" in Rokan Hilir Regency is giant tiger prawn.

Fishing gear can become sensitive due to improper usage during the fishing process. It is essential for fishermen to utilize appropriate fishing gear to achieve optimal results. Another critical concern is the side effects of sondong, which can lead to the death of various species and the destruction of habitats. Therefore, fishermen must prioritize the efficient and effective use of sondong to minimize harm to the aquatic environment.

3.6 Validity of multidimensional scaling analysis results

The stress value and R^2 value from the MDS analysis are presented in the results of the Monte Carlo analysis, as shown in Table 1. The minimal difference between the MDS analysis index and the Monte Carlo analysis index indicates that the scoring errors are relatively minor. This suggests that the variation in scoring due to differing opinions is also minimal, the repeated analysis process is stable, and the potential for data input errors or missing data is reduced.

Consequently, this implies that the validity of the MDS employed is quite strong for assessing the sustainability of giant tiger prawn management in Rokan Hilir Regency.

Table 1. The differences in sustainability index values in Monte Carlo.

Dimension	Index value		Differences
	Rapfish	Monte Carlo	
Ecological	47.76	47.28	0.48
Economic	46.70	46.65	0.05
Social	55.70	55.24	0.46
Institutional	52.88	52.68	0.20
Technological	46.68	46.53	0.15

The validity of the MDS analysis results can be assessed through the goodness-of-fit values, specifically the stress value and the coefficient of determination (R^2) at a 95% confidence level [34]. Table 2 demonstrates that the stress value is less than 0.25, and the R^2 value is close to 1. This suggests that the validity of the analysis results is statistically supported. Furthermore, it indicates that, in the case studied, the addition of attributes is unnecessary, and the aspects analyzed accurately reflect the actual conditions. The attributes employed effectively explain the sustainability status of the giant tiger prawn, and the results can be utilized for further analysis.

Table 2. The results of the stress value analysis and R^2.

Dimension	Stress	R^2
Ecological	0.17	0.93
Economic	0.16	0.94
Social	0.17	0.93
Institutional	0.16	0.94
Technological	0.16	0.94

Based on Table 2, the stress values generated from all dimensions studied namely ecological, economic, social, technological, and institutional are all less than 0.25, indicating that they fall into the and the R^2 values obtained for each dimension are close to one, exceeding 90%, which aligns with the requirements for the coefficient of determination [35]. This high value suggests that the attributes within each dimension can effectively explain and recommend improvements to the system under investigation.

4 Conclusions

The sustainability status of giant tiger prawn management in Rokan Hilir Regency is less unsustainable. According to the results of the multidimensional scaling (MDS) analysis, the social and institutional dimensions quite sustainable status, with index values of 55.70 and 52.88, respectively. In contrast, the ecological, economic, and technological dimensions demonstrate less sustainable status, with index values of 47.76, 46.70, and 46.48. The sensitive attributes identified through the leverage analysis of each dimension include the range of fishing area, type of giant tiger prawn caught, size of giant tiger prawn, employment, other income outside the fishing business, the amount of subsidy assistance, socialization of fishing, employment level, education, democracy in policy making, the availability of development of fishing community organizations, the selectivity of the fishing gear, fishing aids, and side effects of fishing gear. To address sensitive attributes, it is essential to expand the sustainable capture area, utilize selective capture tools, enhance fishermen education, and engage them in policy-making. Strengthening fishermen organizations and providing appropriate subsidies are also crucial for supporting sustainability.

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