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Sustainability of mackerel fishing (*Scomberomorus commerson*) in Nagari Air Bangis West Pasaman Regency West Sumatra Province

Yani Putri, Zulkarnaini, Hazmi Arief
Department of Fisheries Socio-Economisc, Faculty of Fisheries and Marine, Universitas Riau, Pekanbaru, Indonesia

Abstract
Nagari Air Bangis is the only nagari in the Sungai Beremas District and one of the coastal areas in West Pasaman Regency. This area has significant potential to contribute to its catch, one of which is the mackerel fish. This study aims to assess the sustainability status of the capture fisheries in Nagari Air Bangis. The data processing and analysis were conducted using Multi-Dimensional Scaling-Rapid Appraisal for Sustainability (MDS), which is a modification of Rapid Appraisal for Fisheries (Rapfish) utilizing five dimensions: ecological, economic, social, institutional, and technological. The overall research results show that the highest sustainability index is in the social dimension at 58,83 (fairly sustainable), the economic dimension at 56,88 (fairly sustainable), the technology dimension at 54,04 (fairly sustainable), the institutional dimension at 47,28 (less sustainable), and the ecological dimension at 45,05 (less sustainable). The social and economic dimensions have a significant impact on the sustainability of mackerel fisheries in Nagari Air Bangis, West Pasaman Regency.

Keywords: Makerel fish, sustainability, MDS-Rap

Introduction

Sustainability has become a buzzword in almost all development activities, especially since the birth of global agendas such as the Millennium Development Goals (MDGs) to the latest, which we know as Sustainable Development Goals (SDGs) which emphasize the importance of balance between nature and humans to support welfare at large [1]. Fisheries is one of the sectors relied upon for Indonesia's future development, acting as a source of state income, food provider, and livelihood for coastal communities. Capture fisheries in Indonesia require planned management so that capture fisheries activities can be sustainable [2].

Sustainable fisheries aim to strengthen the capture fisheries and aquaculture sectors in meeting nutritional needs, food security, and conservation of fish resources. The development of the fisheries sector must be carried out in a sustainable manner in ecological, economic, social, technological and institutional aspects, as stipulated in the FAO Code of Conduct for Responsible Fisheries (CCRF). Sustainability not only includes aspects of fishing, but also the sustainability of the social community of fisheries communities through a participatory approach that involves stakeholders in the management and conservation of resources [3].

Nagari Air Bangis is located in Sungai Beremas Subdistrict and is known as one of the nagari with relatively large capture fisheries compared to other nagari in the West Coast of West Pasaman. Fisheries entrepreneurs in Nagari Air Bangis have played an active role in advancing local fisheries production. Their active role is evident from the number and size of fleets and fishing gear operated, which are relatively larger, resulting in greater production outputs [4].

The marine fisheries production in the waters of West Pasaman Regency's capture fisheries sector reached 100,871 tons in 2023. A significant portion of this production, totaling 50,436 tons, came from Sungai Beremas District [5]. Among the various marine fisheries products in Sungai Beremas, one notable species is mackerel (*Scomberomorus commerson*). Mackerel is a primary target species for fishermen in the Pacific West region of Indonesia [6]. Known internationally as narrow-barred Spanish mackerel, it holds high economic value. The rising domestic and export demand has increased exploitation pressures, highlighting the need for the adoption of appropriate fishing technologies. These technologies must align with environmental conservation and sustainability efforts [7]. Over the past five years, the average mackerel fishing production in the waters of Sungai Beremas District has been approximately 22, 24 tons.

Capture fisheries require planned management to ensure that the activities of fishermen can be sustainable. By considering the characteristics of mackerel fisheries in Nagari Air Bangis and the existence of the fisheries sustainability assessment concept, it is necessary to examine how the sustainability of mackerel capture fisheries stands from several dimensions of sustainability, including ecological, economic, social, technological, and institutional dimensions. These sustainability aspects can serve as a basis for assessing the sustainability status of a fishing area, providing a reference for formulating policies for sustainable fisheries resource management [2].

The topic of mackerel sustainability in Nagari Air Bangis needs to be studied because mackerel production in Nagari Air Bangis has decreased significantly in the last 5 years, with an average decrease of 24,95% each year. This decline is a concern because mackerel is a commodity with high economic value. In the future, it is estimated that the demand for this commodity both in fresh and processed form will continue to increase. In fact, most of the mackerel catch in Nagari Air Bangis is exported to Malaysia and Singapore through the port of Dumai. Threats such as overfishing, climate change, and marine pollution need to be investigated further to protect the mackerel population. The results of this study are expected to provide data and recommendations for the government and related institutions in formulating sustainable fisheries policies.

Research methods

Time and place

The time of this research was from June 27 to July 06, 2024 in Nagari Air Bangis, West Pasaman Regency, West Sumatra Province.

Research methods

The method used in this research is the survey method. The researcher utilizes questionnaires and structured interviews as data collection instruments, aiming to gather information from a sample of respondents who represent a specific population, and to analyze the data statistically to test the proposed hypotheses. The survey method is employed to obtain data from a particular natural setting, but the researcher intervenes in the data collection process, for example, by distributing questionnaires, conducting structured interviews, and so on [8].

Determination of respondents

This study used purposive sampling method with certain criteria, namely *gill net* and *trammel net* fishers, marine and fisheries extension workers, community leaders, non-governmental organizations (NGOs), and marine and fisheries agencies. The number of gill net and trammel net fishermen in Nagari Air Bangis is 371 people [5]. The sample is part of the population that represents its characteristics. If the subject is less than 100, the entire population is sampled, but if more than 100, 10-25% is taken [9]. The researchers took 10% of 371 gill net and trammel net fishermen, so the number of fishermen samples was 37 people. The respondents of this study consisted of 41 people, including 37 gill net and trammel net fishermen, 1 marine and fisheries extension agent, 1 community leader, 1 NGO member, and 1 staff of the marine and fisheries office.

Data collection

The data collection techniques used in this study include observation, interviews with guided questionnaires, and literature review. The data collected in this research consists of both primary and secondary data. Primary data is obtained through questionnaires and structured interviews with fishermen. Secondary data is collected from literature studies.

Data analysis

Data processing and analysis methods were carried out using the Multi-Dimensional Scaling-Rapid Appraisal for Sustainability (MDS) approach, which is a development of Rapid Appraisal for Fisheries (Rapfish) using 5 dimensions, namely ecological dimensions, economic dimensions, social dimensions, technological dimensions, and institutional dimensions. Rapfish (Rapid Appraisal for Fisheries) is an analytical method for evaluating the sustainability of fisheries in a multidisciplinary manner based on the ordination technique (placing something in order of measurable attributes) with Multi-Dimensional Scaling (MDS). MDS itself is basically a statistical technique that tries to transform multidimensionality into lower dimensions [10].

The stages of MDS analysis include (1) determining attributes, this study uses 30 attributes in 5 dimensions, namely 6 attributes each in the ecological, economic, social, technological, and institutional dimensions; (2) assessment of each attribute on an ordinal scale (scoring) based on the sustainability criteria for each dimension; (3) Rapfish ordination analysis using the MDS method to determine ordination and stress values; (4) assessment of sustainability indices and status both for each dimension and multidimensionally, with reference to the criteria set by Kavanagh & Pitcher [11]; (5) sensitivity analysis (leverage analysis) to determine sensitive attributes that affect sustainability [12]. Determination of the sensitivity attributes of the sustainability of mackerel capture fisheries in Nagari Air Bangis using Pareto optimum analysis of 75% by accumulating attributes with the highest RMS value; (6) Monte Carlo analysis to determine the stability of the ordination results.

Table 1: Sustainability status index categories

Index	Category
0-25	Bad
26-50	Less
51-75	Enough
76-100	Good

Source: Nababan *et al*., (2007) [2]

Results and discussion

Overview of the research location

This research was conducted in Nagari Air Bangis, Sungai Beremas District, West Pasaman Regency, West Sumatra Province. Geographically, Nagari Air Bangis is located at coordinates 00º09'-00º31' LU and 99º10'-99º34' East, with an altitude of 0-319 meters above sea level and an area of 440,48 km², which covers 11,33% of the total area of West Pasaman Regency [13]. This Nagari borders Ranah Batahan Regency to the north, the Indonesian Ocean to the south, North Sumatra Province to the west, and Koto Balingka District to the east. Nagari Air Bangis is the only nagari in Sungai Beremas Sub-district, which previously consisted of nine villages which are now called jorong after the division in 2003 [14]. Nagari Air Bangis has 9 islands including Panjang Island, Pigago Island, Tolua Island, Tamiang Island, Pangka Island, Unggeh Island, Tiger Island, Fish Island, and Tabaka Island [15].

Capture fisheries sector

Nagari Air Bangis is located in Sungai Beremas District, West Pasaman Regency, West Sumatra Province which is one of the largest fish producers in this area. With a coastline length of 72,56 km. One of the main commodities is mackerel, which has a high price and many enthusiasts, so it is exported to Malaysia and Singapore through the port of Dumai. The average mackerel production in the last 5 years in Nagari Air Bangis reached 22,24 tons, can be seen in Table 2.

Table 2: Mackerel Fish Production in Nagari Air Bangis

No	Year	Value (Rp)	Production (Ton)	Develop-ment (%)
1	2019	2.845.486.800	54,72	0,00
2	2020	1.590.934.000	32	-41,52
3	2021	649.997.000	10,4	-67,5
4	2022	365.176.000	5,5	-47,12
5	2023	576.114.000	8,6	56,36
Average			22,24	-24,95

Table 2 shows that mackerel production in Nagari Air Bangis has decreased by 24,95% annually over the past five years. This decline is influenced by factors such as

overfishing, climate change, marine habitat degradation, and insufficient fisheries management and regulations.

Sustainability of mackerel capture fisheries in nagari air bangis

The sustainability of mackerel capture fisheries in Nagari Air Bangis was analyzed using the Multi Dimensional Scalling method using Rapfish (Rapid Appraisal Technique for Fisheries) which is used to estimate the level of sustainability in mackerel capture fisheries from various dimensions. Rapfish produces index values and sustainability status of each dimension and multidimensional mackerel capture fisheries in Nagari Air Bangis. Determination of the sustainability status of mackerel capture fisheries using 5 dimensions, namely ecological, economic, social, technological, and institutional.

Ecological dimension

In maintaining the availability and sustainability of fish resources, it is necessary to take a precautionary approach in the exploitation of fish resources so that the ecological sustainability of capture fisheries can be maintained. Therefore, in the exploitation of fisheries resources, it is necessary to estimate the potential of fisheries resources that can provide an overview of the level and maximum limit in the utilization of fisheries resources in an area, so that fisheries development can be planned in such a way and fisheries resources can be utilized sustainably [16].

The results of Rapfish analysis on the ecological dimension showed a value of 45,05 the value is classified as less sustainable status (26-50).

The ecological dimension has a less sustainable status, which can be characterized by the high level of collapse (decrease in the number of fish caught) and the presence of by-catch in Nagari Air Bangis, this will certainly have a negative impact on the mackerel population and other fish. This could threaten the sustainability of the marine ecosystem, reduce biodiversity, and worsen the economic welfare of fishermen who depend on their daily catch. In the long run, this situation could lead to dependence on government subsidies and disrupt the balance of the fisheries ecosystem in the region. To see the attributes that have an influence on the sustainability of the ecological dimension, a leverage analysis is needed. The results of the leverage analysis obtained the Root Mean Square (RMS) value of each ecological dimension attribute. The RMS value indicates the level of influence of the attribute on the sustainability index value. Attributes that have the greatest influence are indicated by the largest RMS value and vice versa attributes with the smallest RMS value have little influence on the value of the sustainability index [12].

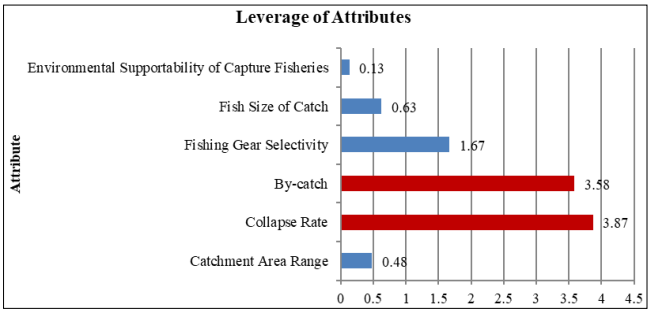

Fig 1: Leverage analysis results of the Ecological dimension

To determine the attributes sensitive to sustainability using pareto analysis, namely by sorting the magnitude of the RMS value of the results of sensitivity analysis (leverage analysis) from the largest value to the smallest value, then weighting is done in the form of a percentage after which it is accumulated. Furthermore, attributes are taken until the maximum cumulative value limit reaches 75% [12]. Based on Pareto analysis, two attributes were found to be sensitive to the ecological dimension sustainability index value, namely the collapse rate with a value of 3,87 and by-catch with a value of 3,58 (Figure 1). The collapse level indicates that fewer signs of fish stock decline over a wide area reflect a healthy ecosystem. Consequently, the risks and threats to fisheries sustainability in the region are reduced, and fewer bycatch fish signify more efficient utilization of fishery resources [17]. This means that in formulating policies to improve the sustainability status of the ecological dimension, it is necessary to pay attention to and consider these two attributes.

Economic dimension

The economic dimension aims to achieve optimal profits to support the sustainability of an area. Mackerel capture fisheries activities provide a fairly good economic income for fishermen, so that they can support the sustainability of mackerel capture fisheries in the research location in the future. The economic sector needs to be considered and management efforts made so that the community gets welfare.

Rapfish analysis results show a value of 56,88. This value is classified as a fairly sustainable status (51-75). From an economic perspective, the mackerel capture fisheries in Nagari Air Bangis are still considered relatively sustainable, as the average fisherman owns their own vessel. The marketing distribution of the catch is also classified as good, covering local markets, district-level markets, inter-provincial markets, and even international export markets. However, it is possible that this status may decline with the diminishing population of mackerel and other fish species, as evidenced by the decrease in fishermen's income over the last five years. If the trend of declining fish populations continues, not only will fishermen's incomes continue to drop, but it will also affect their competitiveness in the export market and increase dependence on increasingly scarce natural resources.

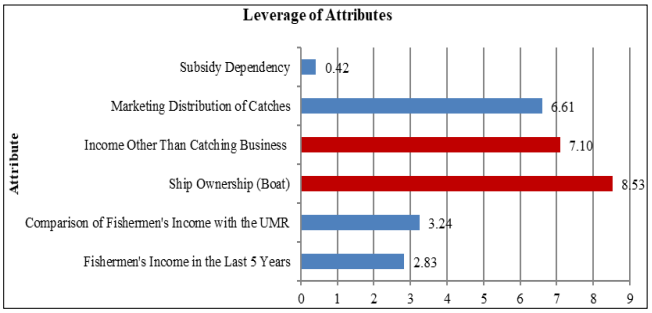

Fig 2: Leverage analysis results of the Economic dimension

Based on the leverage analysis results for the economic dimension, two key attributes with high leverage values are vessel ownership (boat) with a value of 8,53 and income from sources other than fishing activities with a value of 7,10 (Figure 2). The ownership nature of fishing facilities

ultimately relates to the distribution of profits from fisheries operations18. This indicates that when formulating policies to improve the sustainability status of the economic dimension, attention must be given to and consideration should be given to these two attributes.

Social dimension

In general, Indonesia has a diverse culture that impacts the diversity of its social environment. This diversity in the social environment can form due to the dynamics of different communities, geographical conditions, and various ecosystems. Thus, the social environment diversity in Indonesia can be observed based on locality/geography, divided into coastal and inland environments, or aquatic and terrestrial areas16. The majority of the population in Nagari Air Bangis is Muslim, and most are from the Minang/Malay ethnic group. However, there are also many other ethnic groups in the area. The social status in Nagari Air Bangis also varies, similar to other fishing communities. This diversity needs to be unified to achieve harmony in society.

The Rapfish analysis results for the social dimension show a value of 58,83. This value is classified as a fairly sustainable (51-75). In the social dimension, the mackerel capture fisheries in Nagari Air Bangis have a fairly sustainable status. This can be seen from the existence of community empowerment programs through the fisheries office, as well as regular extension and training sessions for fishermen, which are conducted twice a month for each group of fishermen in Nagari Air Bangis. However, this status may decline due to certain attributes that have a "bad" value, such as the presence of conflicts within the community and the generally low education level (average junior high school). If conflicts within the fishing community are not addressed promptly, they could disrupt cooperation among fishermen and weaken social solidarity in resource management. Meanwhile, the low education level could hinder fishermen's ability to adapt to new technologies and more sustainable fishing strategies

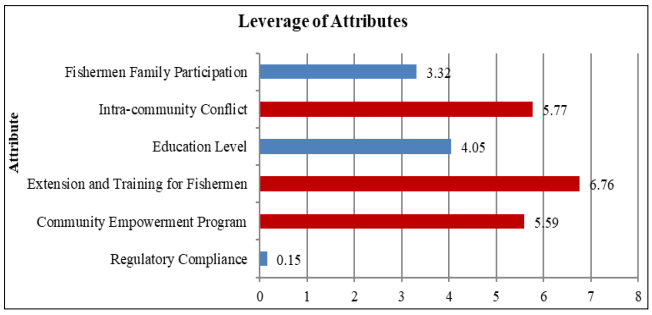

Fig 3: Leverage analysis results of the Social dimension

Based on the leverage analysis results for the social dimension, three key attributes with high leverage values are fisheries extension and training for fishermen with a value of 6,76, followed by community conflicts with a value of 5,77, and community empowerment programs with a value of 5,59 (Figure 3). The development of non-formal education through extension and training enhances the capacity of fishermen. Empowering fishermen is key to national fisheries development by improving their knowledge and skills to strengthen their bargaining power [19]. Community empowerment is crucial for boosting the economy while preventing the negative environmental impacts of coastal development. The government needs to play an active role in raising awareness about sustainability by providing facilities and financial support [20]. Conflicts among fishermen arise due to unclear policies made by the relevant authorities. The status and frequency of conflicts indirectly cause setbacks in fisheries activities, as fishermen face material and psychological losses [16]. This indicates that when formulating policies to improve the sustainability status of the social dimension, it is crucial to pay attention to and consider these three attributes.

Technology dimension

The development of technology in the capture fisheries sector generally aims to increase capture productivity to meet the growing demand for consumption, both for local and international markets. On the other hand, the improvement and development of capture technologies also aim to enhance the competitiveness among fishermen due to the increasingly limited fish resources. The shift towards more effective technologies may, in some specific locations, lead to a decrease in fish resource availability. The study of this technological dimension is crucial because the application of technology can reflect the level of technology adoption by the community. In the capture fisheries sector, the application of technology can also illustrate the scale of business or the cluster of capture fisheries [16].

The Rapfish analysis results for the technology dimension show a value of 54,04. This value is classified as a fairly sustainable (51-75).

The technology dimension has a fairly sustainable status because fishermen in Nagari Air Bangis already use modern types of ship engines, have a centralized fish landing site, the handling process on the ship is quite good, and use a ship size ≥ 5 GT which is very suitable for the water conditions in Nagari Air Bangis. In addition, the use of navigation aids such as GPS and fish finder has helped fishermen in improving fishing efficiency. However, the sustainability status of the technological dimension needs to be improved, seeing the inadequate infrastructure of the fish landing site so that more attention is needed from the agency and government. In addition, increased access to training in the use of new technologies and the development of innovations in catch processing need to be encouraged, especially in the face of climate change challenges and dependence on declining fish resources.

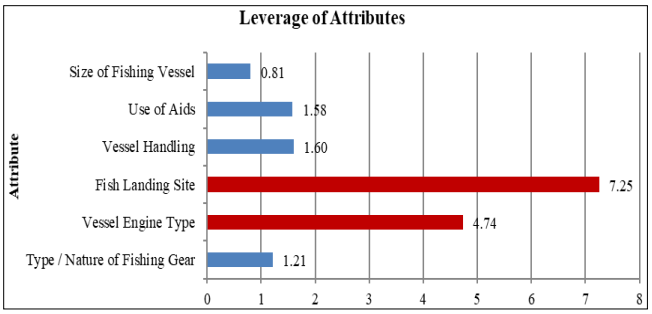

Fig 4: Leverage analysis results of the Technology dimension

Based on the leverage analysis results for the technology dimension, two key attributes with high leverage values are fish landing sites with a value of 7,25 and the type of boat engine with a value of 4,74 (Figure 4). Fish landing sites are locations where caught fish are processed, sold, or stored, and are an important part of the fisheries supply chain to ensure quality and operational efficiency. Vessel engine

type is a critical component in fisheries that affects vessel efficiency and performance. Proper engine selection based on needs, costs, and operational conditions affects the power, speed, and capability of the vessel. This indicates that when formulating policies to improve the sustainability status of the technology dimension, it is important to pay attention to and consider these two attributes.

Institutional dimension

Institutional aspects are one of the criteria and indicators of a sustainable fisheries system, serving as a foundation for creating policies that align with needs and strengthen the implementation of laws. Therefore, a good policy can be effective when accompanied by strong legal enforcement [16].

The Rapfish analysis results for the institutional dimension show a value of 47,28. This value is classified as less sustainable (26-50).

The sustainability of the institutional dimension in mackerel capture fisheries in Nagari Air Bangis, West Pasaman Regency, has a less sustainable status. This is marked by the fact that environmental monitoring is solely delegated to the government, a lack of efforts to prevent or reduce marine ecosystem damage, and the limited role of fishermen in decision-making. To ensure sustainability, increased collaboration between the government, fishermen, and non-governmental organizations (NGOs) is necessary for environmental monitoring and protection. Additionally, empowering fishermen to be more involved in decision-making processes and implementing ecosystem damage mitigation programs are crucial steps to maintain more sustainable fisheries that are responsive to environmental changes.

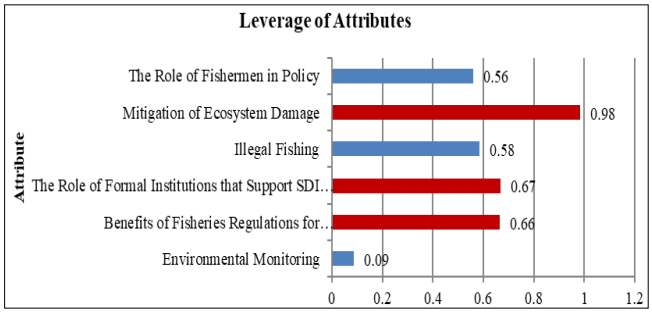

Fig 5: Leverage analysis results of the Institutional dimension

Based on the leverage analysis results for the institutional dimension, three key attributes with high leverage values are ecosystem damage mitigation with a value of 0,98, the role of formal institutions supporting the management of fishery resources (SDI) with a value of 0,67, and the benefits of fisheries regulations for fishermen's welfare with a value of 0,66 (Figure 5). Mitigation of ecosystem damage in Nagari Air Bangis still requires a greater contribution to support sustainability. This is influenced by the limited knowledge of fishermen regarding mitigation systems and ecosystems. Therefore, extension and training are necessary to improve knowledge, skills, and awareness within the community about the importance of preserving and mitigating ecosystems [10]. Institutional development by local governments has a positive impact, not only facilitating access to government assistance but also enhancing fishermen's legal literacy regarding regulations in the fisheries and marine sectors [20]. This indicates that when formulating policies to improve the sustainability status of the institutional dimension, it is important to pay attention to and consider these three attributes.

Multidimensional sustainability status

The sustainability index of each dimension does not yet reflect the overall sustainability status of the activity. For this reason, the index value of each dimension needs to be combined to determine the value of multidimensional sustainability status [21]. The results of the MDS analysis of the combination of 5 dimensions obtained a multidimensional sustainability index value of mackerel capture fisheries in Nagari Air Bangis of 52,42 (Table 3).

Table 3: Multidimensional sustainability index values

No	Dimension	Dimensional Value
1	Ecology	45,05
2	Economy	56,88
3	Social	58,83
4	Technology	54,04
5	Institutional	47,28
Multidimensional Index Value		52,42

Accuracy analysis (goodness of fit)

The stress value and coefficient of determination are used to see the extent of the accuracy of the results of the sustainability index value or in other words whether or not it is necessary to add attributes to reflect the level of accuracy of the five dimensions studied so that it can be scientifically accounted for [22]. Stress values obtained from five dimensions, namely ecological, economic, social, institutional and technological dimensions are smaller than 0,25. Meanwhile, the R-Square value of the five dimensions shows a value close to 1 or >90%, as can be seen in Table 4.

Table 4: Stress and R-square values

No	Dimension	Stress Value	R^2
1	Ecology	0,16	0,94
2	Economy	0,15	0,94
3	Social	0,15	0,94
4	Technology	0,15	0,94
5	Institutional	0,17	0,93

Monte carlo analysis

To assess the impact of errors or disturbances on the ordination results of mackerel fisheries sustainability, Monte Carlo analysis was conducted. This statistical simulation method evaluates the effects of errors or disruptions in the statistical process.

Table 5: Difference between Rapfish and Monte carlo Sustainability Index Values

Sustainability Dimension	Sustainability Index Value		Difference
	Rapfish	*Monte carlo*	
Ecology	45,05	45,38	0,33
Economy	56,88	55,66	1,22
Social	58,83	58,60	0,23
Technology	54,04	53,45	0,59
Institutional	47,28	47,00	0,28

The Monte Carlo value at a 95% confidence level is nearly identical to the MDS value, indicating minimal data analysis

error. A difference of <2 in each dimension suggests that scoring and score variation are relatively accurate, and missing data errors have been avoided [19].

Conclusion

The results of the analysis using MDS (Multi-Dimensional Scaling) Rapfish show that the mackerel (*Scomberomorus commerson*) capture fishery in Nagari Air Bangis, West Pasaman Regency, is categorized as fairly sustainable with a score of 52,42. The highest value is found in the social dimension at 58,83 (fairly sustainable), followed by the economic dimension at 56,88 (fairly sustainable), the technology dimension at 54,04 (fairly sustainable), the institutional dimension at 47,28 (less sustainable), and the lowest value is in the ecological dimension at 45,05 (less sustainable).

Sensitive attributes in the mackerel capture fishery in Nagari Air Bangis, West Pasaman Regency, include attributes such as boat ownership, fish landing sites, income from sources other than fishing, extension services and training for fishermen, conflicts within the community, and community empowerment programs.

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