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Sustainability Analysis of the Grouper Fishing Based on the "Sasi" Local Wisdom on Ayau Island, Raja Ampat, Indonesia, Using Multidimensional Scaling Analysis Approach

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ABSTRACT

Grouper management is crucial in Indonesia due to its high economic and ecological value. Uniquely, on Ayau Island, Indonesia, grouper management is approached using locals known as Sasi. This study aimed to analyze the sustainability status of the grouper fishery on Ayau Island, which utilizes the Sasi Law. Primary data were collected through interviews with local fishermen and traditional figures. Direct observations were made on the fishing grounds to observe the operational aspects. Secondary data were obtained from the marine and fisheries service of Raja Ampat Regency. A multidimensional scaling (MDS) techniques werer used for data analysis with the RAPFISH tool to assess five dimensions of fisheries sustainability: ecological, economic, social, technological, and institutional. The results show that the economic dimension has the highest sustainability index, while the technological dimension has the lowest. This reveals that local fishermen are in need of the support and attention of the local government. The attribute of compliance with regulation represents Sasi Law and is included in the social dimension. The results highlight the importance of Sasi Law, which exhibits high sensitivity values. This research underscores the diverse dimensions and attributes ensuring the sustainability of grouper fisheries, with Sasi Law serving as a key parameter in the social dimension.

INTRODUCTION

The marine and fisheries sector has become the primary focus of global socio-economic activity **(Lu *et al.*, 2015)**. Coastal and marine ecosystems are crucial in driving the global economy, particularly for maritime countries that benefit significantly from marine product trade **(Day *et al.*, 2015; Laffoley *et al.*, 2019)**. Therefore, maintaining these resources is of utmost importance. Grouper is an important fishery resource due to its nutritional content and consequently high economic value **(Rimmer & Glamuzina, 2017)**. Additionally, groupers are one of the most diverse families of percoids, with 167 species classified into 15 genera **(Félix-Hackradt *et al.*, 2022)**. According to **FAO**

(2021), Indonesia's grouper production has exceeded 100,000 tons in recent decades. As a preferred commodity, demand for grouper remains high in international markets, particularly in Hong Kong and China **(Suhana *et al.*, 2021)**.

Currently, groupers are critical commercial species and are managed by small-scale fishers **(Halim *et al.*, 2020; Achmad *et al.*, 2022)**. Small-scale fisheries (SSF) in Asia-Pacific contribute significantly to fish consumption compared to industrial fisheries **(Bene *et al.*, 2016)**. However, uncontrolled grouper fishing by small-scale fishermen may lead to overfishing **(Efendi, 2021)**. This threatens the long-term survival of the fishing industry and could ultimately lead to species extinction **(Pham *et al.*, 2023)**. Uniquely, the Ayau Islands community has adopted regulations to manage marine products including grouper. This regulation is based on local wisdom known as "Sasi Law", an effort to regulate marine and forest resources by opening and closing fishing areas to ensure that resources remain available for future generations **(Djaiz *et al.*, 2019; Lewerissa *et al.*, 2021; Alvayedo & Erliyana, 2022)**. More specifically, the aim of implementing the "Sasi Law" is to ensure that natural resources are used wisely and sustainably over time time **(Sokoy, 2022)**.

The Ayau Islands are divided into two areas, including Ayau District and Ayau Islands District, which together encompass nine villages with a population of more than 2,000 people. Historically, the population of the Ayau Islands consists of descendants of the Biak ethnic group, including the Wardo and the Usba sub-ethnic group. The community's primary source of income comes from marine products, particularly the grouper. The Sasi concept is regarded as a natural resource management model that integrates local knowledge and experiences to ensure ecosystem sustainability **(Subekti & Budiana, 2019)**. For many years, the people of the Ayau Islands have recognized the Sasi custom as a sign of the beginning and end of the harvest season **(Nurannisa *et al.*, 2020)**. For example, a previous review reported an increase in sea cucumber production after the implementation of Sasi in Raja Ampat Regency **(Boli *et al.*, 2014)**. Similarly, grouper resources on Ayau Island require a clear status assessment as a prudent step in managing marine products. Therefore, mathematical analysis is required to establish the resource status and prevent value degradation.

The multidimensional scaling (MDS) approach is one of the well-turned methods for assessing fisheries' sustainability, as it provides an overview of fisheries' performance across various aspects to evaluate sustainability. Determining the status of fisheries resources integrately includes 4 aspects: ecology, economics, society, and technology **(Alder *et al.*, 2000)**. RAPFISH is a multidisciplinary rapid assessment technique that has been widely used for assessing sustainable fisheries management **(Fauzi & Anna, 2002; Nababan *et al.*, 2007; Abdullah *et al.*, 2011)**. In this analysis, fisheries are defined flexibly as entities with a broad scope, including all fisheries in the sea and lakes **(Pitcher & Preikshot, 2001)**. Technically, RAPFISH uses an ordinance approach by placing measurement attributes/parameters in a certain sequence. Then, the

statistical principle of MDS is used to transform multi-dimensional data into lower dimensions **(Fauzi & Anna, 2002; Suharno *et al.*, 2019)**.

Thus far, numerous studies have been conducted on Sasi Law **(Wahyono, 2000; Mustaghfirin, 2012; Adhuri, 2013; Boli *et al.*, 2014; Sumarsono & Wasa, 2018; Adiastuti *et al.*, 2019; Putri *et al.*, 2020)**. However, there has been little discussion regarding the impact of the Sasi Law on resource sustainability, especially in grouper fisheries. In fact, this approach is ideal for promoting cultural sustainability while also contributing to sustainable resource management **(Adhuri, 2013)**. Furthermore, the application of similar approaches to marine preservation highlights the diverse benefits they provide globally **(Day *et al.*, 2015)**. Therefore, assessing the sustainability of the grouper fishery managed through the Sasi Law is fundamental. Based on the aforementioned data, this study aimed to analyze the sustainability of grouper fishing managed under Sasi Law in the Ayau Islands, Raja Ampat Regency, Indonesia.

MATERIALS AND METHODS

1. General description technique of data collection

The study was conducted in the Sasi customary land rights area in the Ayau Islands, Raja Ampat Regency, Southwest Papua Province, Indonesia (Fig. 1). The study was performed from October 2023 to April 2024. Primary data were collected through interviews using structured instruments (questionnaires), direct observations in the fishing grounds, and literature reviews. Fishing grounds (12 spots) were observed to assess the factual conditions related to the operational aspect. Literature reviews were performed to gather secondary data from official government reports and relevant agencies to support the questionnaire. Secondary data were obtained from the Marine and Fisheries Agency of Raja Ampat. The key respondents included 70 individuals, comprising local fishermen, fisheries entrepreneurs, and representative traditional figures. The results of in-depth interviews with informants were recorded daily in field diaries.

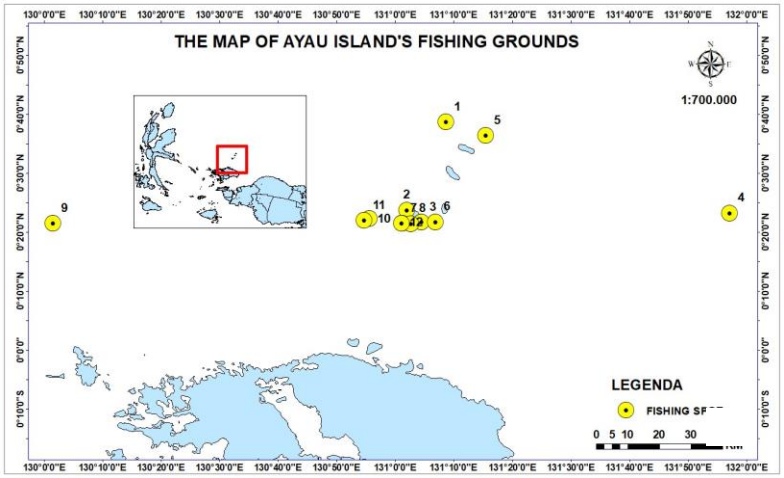

Fig. 1. The map of the study site on Ayau Island, eastern Indonesia

2. Method approach

2.1. RAPFISH analysis

The sustainability status of groupers on the Ayau Islands was evaluated from a multidisciplinary perspective using the multi-dimensional scaling (MDS) method recognized as RAPFISH (*Rapid Appraisal for Fisheries*). RAPFISH is a multidisciplinary analytical tool for evaluating fisheries' sustainability. It is based on the methodology of ordination (arranging items according to measured attributes) and multidimensional scaling. The dimensions used in this research refer to **Nababan *et al.* (2007)**, who outlined a comprehensive approach to assessing the sustainability status of fisheries resources from five aspects: (1) environment; (2) economics; (3) technology; (4) social; and (5) institutional. Furthermore, the attributes within each dimension were determined based on references from the FAO Code of Conduct, the EAFM (*ecological approach of fisheries management*) **(FAO, 2014)**, and relevant previous studies.

2.2. Attributes criteria

The attributes required for this study were:

1) Ecological : Environmental parameters
2) Economic : Costs and revenue aspects
3) Social : Social and anthropological aspects
4) Technological : Technological utilization aspect
5) Institutional : Fishermen's group, government, and traditional figures

A set of six attributes for each ordination deemed crucial to grouper sustainability has been defined. The attributes were selected to maximize discriminating power in the ordination process, ensuring that outliers do not disproportionately affect the result. The attribute criteria were chosen as they are objectively scored, clearly classified, and easily described as `good' or `bad' in terms of sustainability. Furthermore, the scores are available for all fisheries and periods included in the analysis.

3. Data analysis

The sustainability value of each dimension is expressed as the sustainability index, as outlined by **Nababan *et al.* (2007)**. To facilitate the interpretation of the results, the values are grouped into four intervals as explained in Table (1). Each attribute is scored by reviewing the research data as presented in Table (2). In addition, the RAPFISH approach uses the ALSCAL algorithm application method in statistical software (Ms. Excel).

Table 1. The interval of the MDS sustainability analysis index

No	Sustainability index interval	Sustainability status
1.	0 – 25	Not sustainable
2.	26 – 50	Less sustainable
3.	51 – 75	Fairly sustainable
4.	76 – 100	Sustainable

Table 2. Attributes of grouper resource management on the Ayau Islands

No	Attributes	Criteria and score
	Ecological dimension	
1	Range collapse	0= Closer; 1= stagnan; 2= moderate; 3= far; 4= very far
2	Change in catch size	0= Bigger; 1= stagnan; 2= smaller
3	Coral reefs condition	0= >85%; 1=76-85%; 2= 51-75%; 3= 26-50%; 4= <25%
4	Use of illegal fishing gear	0= None; 1= exist
5	Selectivity of fishing gear	0= High (<50%); 1= moderate (50-75%); 2= low (<50%)
6	Fishing duration	0= Faster; 1= stagnan; 2= longer
	Economic dimension (*RMW= regional minimum wage****)***	
1	Fisherman's annual income	0= Increased; 1= stagnant; 2= decreasing
2	Number of fishermen	0= Increased; 1= stagnan; 2= decreased
3	Mean age of fishermen	0= <25 years; 1= 25-39 years; 2= 40-54 years; 3= >55 years
4	Comparison of fishermen's income with RMW	0= >RMW; 1= equivalent to RMW; 2= <RMW
5	Ownership of vessel	0=Self owned; 1= owned by group; 2= owned by others
6	Annual operational costs	0= Low (<15%); 1= moderate (15-24%); 2= high (25-29%); 3= vey high (>30%)
	Social dimension	
1	Educational	0= >High school; 1= junior high; 2= elementary; 3= illiterate
2	The existence of fishing groups	0= Exist, functioning; 1=exist, unfunctional; 2= none
3	Fisheries counseling	0= Regular implemented; 1= uncertain; 2= never
4	Government oversight	0= Regular implemented; 1= uncertain; 2= never
5	Compliance with regulations	0= Obedient; 1= quite obedient; 2= disobedient
6	Social conflict	0= Never; 1=sometimes; 2= often (>30%)
	Technology dimension	
1	Willingness to use technology	0= Willing; 1= unwilling
2	Post-harvest technology	0= Frequent used; 1= occasional used; 2 = unuse
3	Type of vessel engine	0= Modern engine; 1= outboard engine; 2=no engine
4	Processing of fishery products	0= Cannning; 1= fumigation; 2= salted; 3= not processed
5	Technological assistance from the government	0= Regular implemented; 1= uncertain; 2= never
6	Utilization of navigation tools	0= Frequently used; 1= sometimes; 2= never
	Institutional dimension	
1	Fishermen's group	0= Exist, functioning; 1 = exist, unfunctioning; 2= none
2	Environmental monitoring	0= Government and community collaborated; 1= community supervision; 2= government supervision; 3= none
3	Influence of traditional figures	0= High; 1= moderate; 2= no effect; 3= no traditional figures
4	Action against illegal fishing	0= Exists; 1= none
5	Guidance by the government	0= Exist, regular; 1 = exist, unregular; 2= none
6	Institutional conflict	0= Never; 1= sometimes; 2= exist

RESULTS AND DISCUSSION

The results of grouper sustainability are represented across five dimensions, as shown in Figs. (2-6). Fisheries sustainability is described quantitatively in numerical analysis using limited multidimensional scaling techniques and leveraged sensitivity analysis.

1. Ecological dimension

The analysis results using RAPFISH on influential attributes show that the sustainability index value for the ecological dimension is 65.16 (Fig. 2). This indicates the sustainability status of grouper fisheries on the Ayau Islands is moderately sustainable.

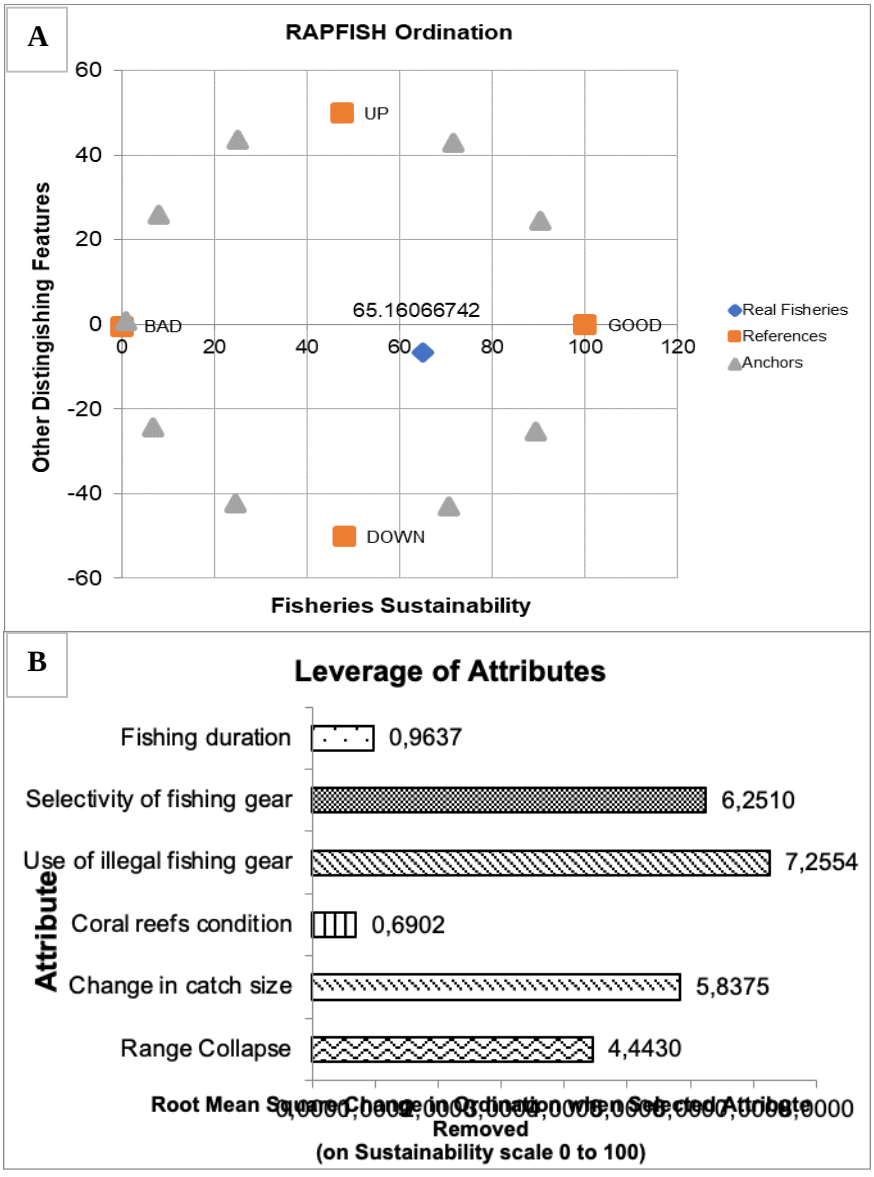

Fig 2. A) Sustainability status of ecological dimensions, and B) sensitivity analysis

A leverage analysis was conducted to determine the effect of sensitive attributes on the sustainability index of the ecological dimension. The results revealed two sensitive attributes: the selectivity of fishing gear with a value of 6.25 and the use of illegal fishing gear with a value of 7.25. Changes to these two items clearly affect the sustainability of grouper in the ecological dimension.

2. Economic dimension

The results of RAPFISH analysis for the economic dimension show a sustainability index of 72.58 (Fig. 3A). The number of fishermen and the ratio of fishermen's income are the most sensitive attributes, with values of 7.25 and 6.56, respectively (Fig. 3B).

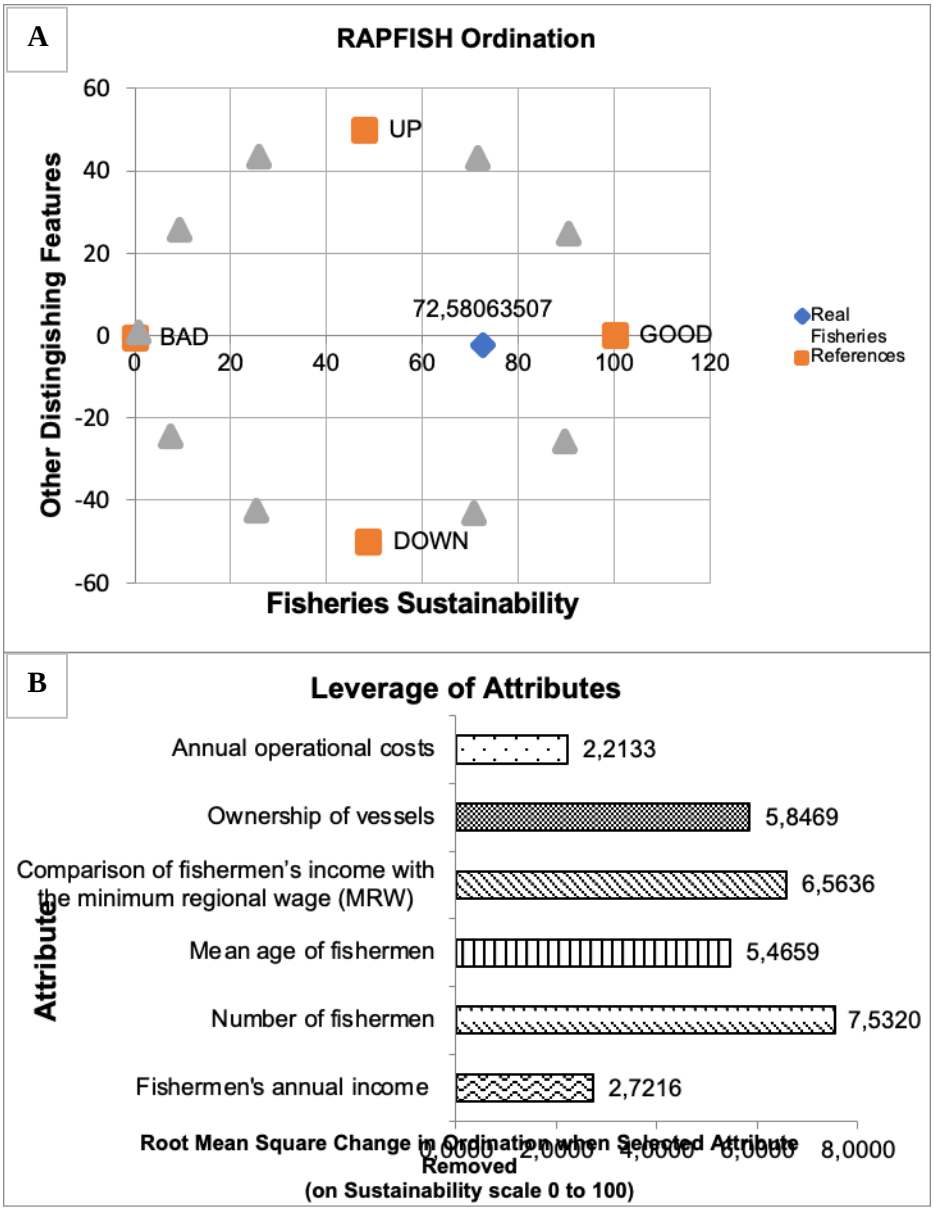

Fig. 3. A) Sustainability status of economic dimensions, and B) sensitivity analysis

Fig. (3) shows the sustainability of grouper fisheries on the Ayau Islands requires government subsidies related to fuel and low-interest capital, as the cost of fishing is quite high. Furthermore, the benefits of grouper fishing are primarily received by external parties such as collectors and traders. Therefore, improving the trading system to favor fishermen is essential.

3. Social dimension

The analysis of the social dimension shows a sustainability index of 40.47 for grouper fisheries (Fig. 4A). These data reveal the status of grouper resources in the Ayau Islands is classified as less sustainable.

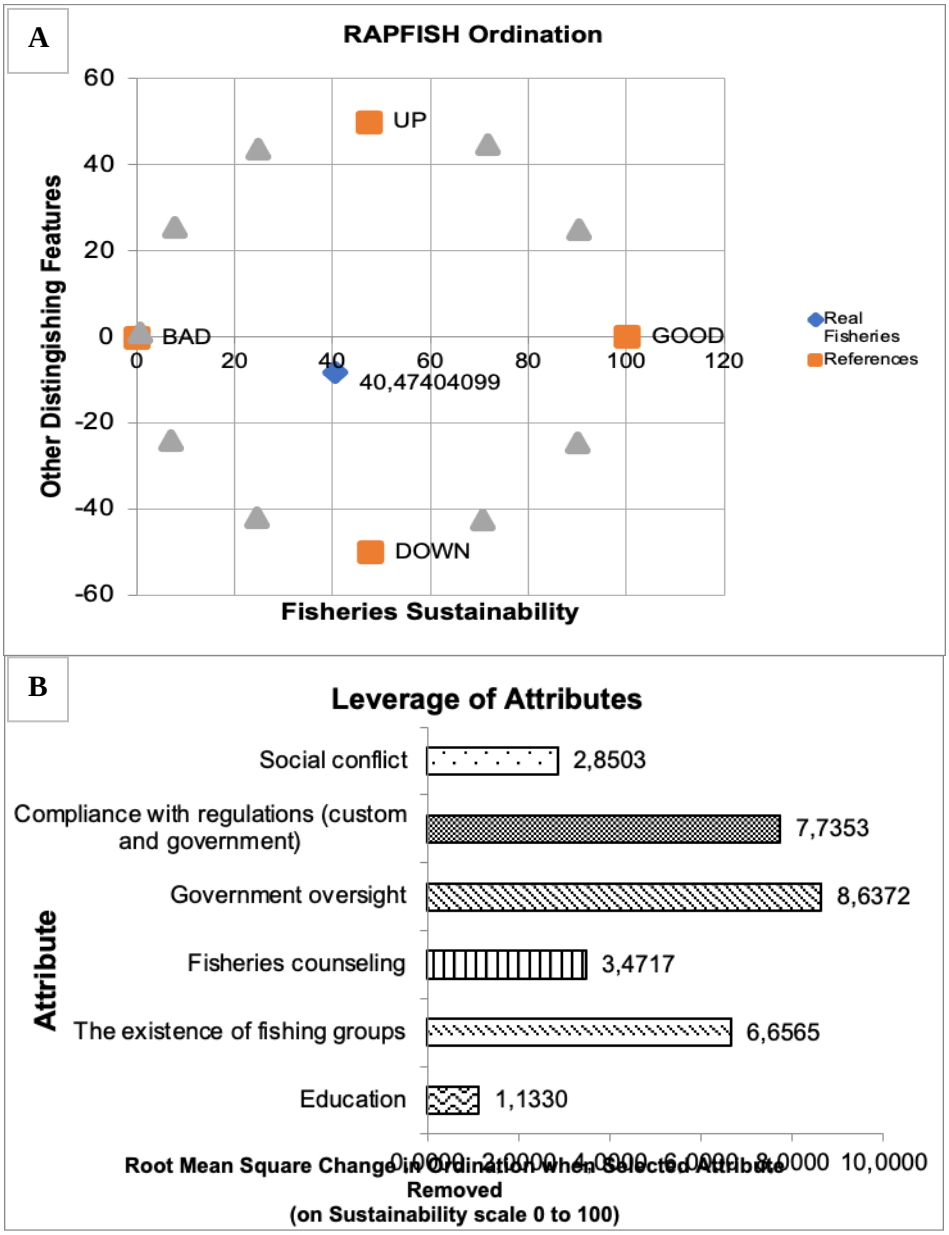

Fig. 4. A) Sustainability status of social dimensions, and B) sensitivity analysis

Three attributes are identified as having the highest sensitivity value (Fig. 4B): compliance with regulations (customary and government), with a value of 7.73; government oversight, with a sensitivity value of 8.63; and the existence of a fishing group, with a sensitivity value of 6.65. Policies aimed at improving sustainability status from the social dimension should consider these three aspects. This is particularly important because the Ayau Islands lacks supervision and counseling from the local government, which affects the quality of the resources. Therefore, synergy between fishermen and the government is important for the sustainable management of grouper fisheries.

4. Technological dimension

The analysis results of the technological dimension show a sustainability index of 33.79 (Fig. 5A). This score is the lowest among all the dimensions.

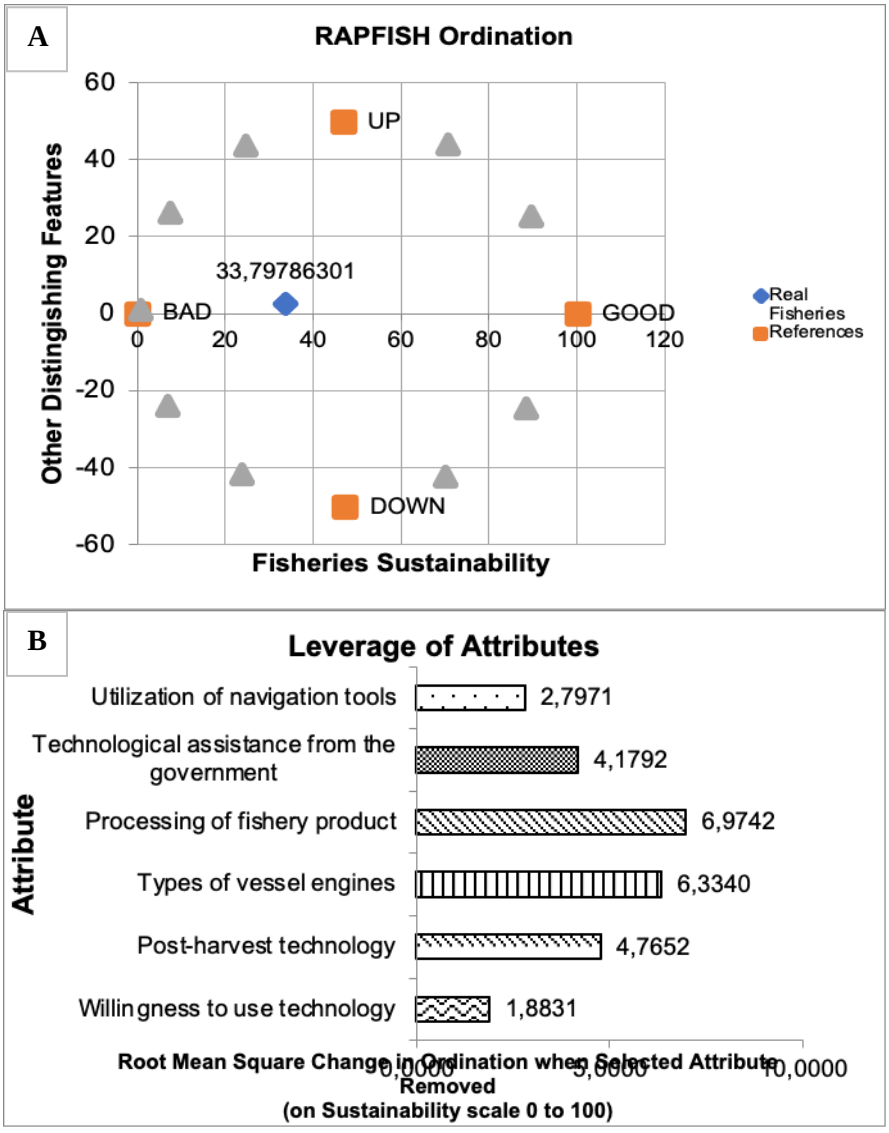

Fig. 5. A) Sustainability status of technological dimensions, and B) sensitivity analysis

Based on this dimension, the status of grouper fisheries on the Ayau Islands is classified as less sustainable, with a score range of 26 to 50. Additionally, the assessment results highlight two attributes with the highest sensitivity values: fishery product processing, with a sensitivity value of 6.97, and types of vessel engines, with a leverage value of 6.33 (Fig. 5B).

5. Institutional dimension

RAPFISH analysis on the institutional dimension shows a sustainability index of 62.31 (Fig. 6A), indicating the status of the grouper fishery on Ayau Island is moderately sustainable, with a score range of 51 to 75. The attribute "action against illegal fishing" is the most sensitive, with a value of 8.04 (Fig. 6B).

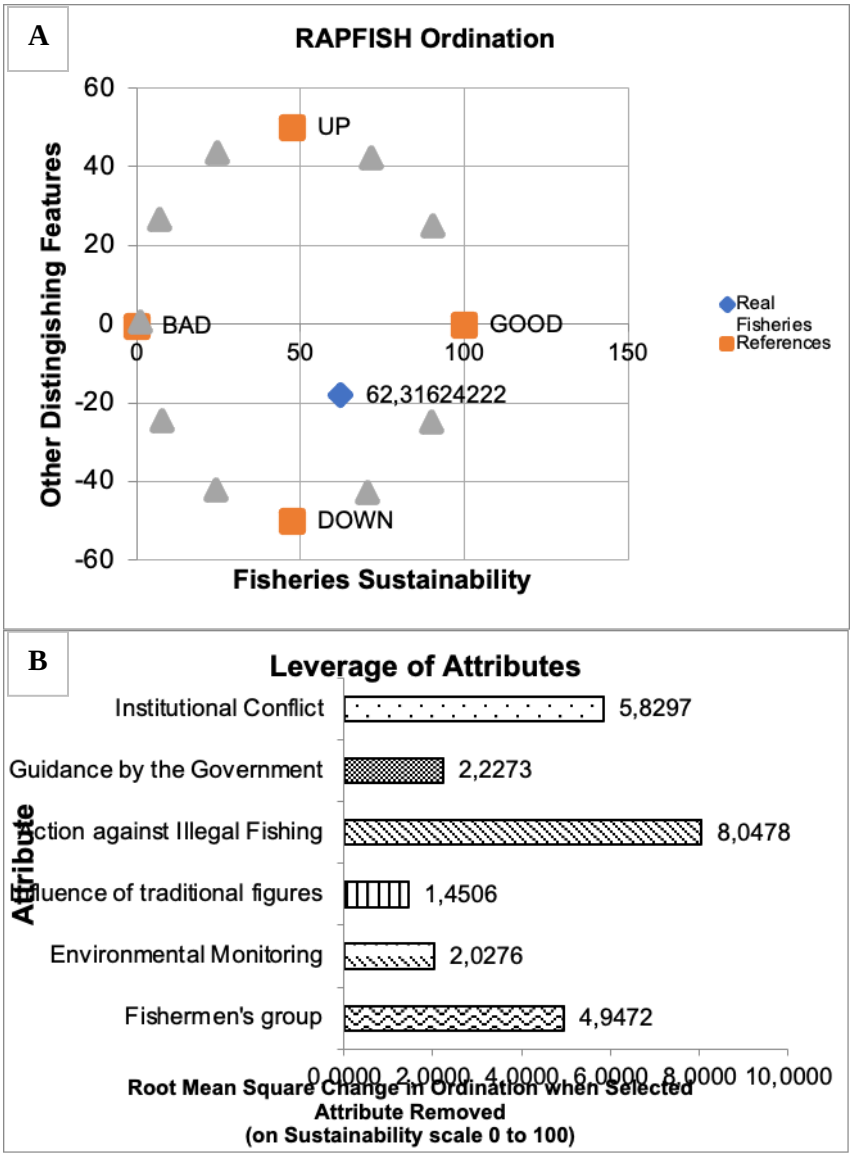

Fig. 6. A) Sustainability status of institutional dimensions, and B) sensitivity analysis

DISCUSSION

RAPFISH provides a quantitative technique for performing interdisciplinary evaluation, which is considered crucial in fisheries management across various aspects **(Lane & Stephenson, 1997)**. Additionally, RAPFISH explicitly uses the qualities that distinguish fisheries, making them usable as attributes in the analysis. The study results across the five dimensions show that the economic dimension has the highest sustainability index among the others, while the technological dimension has the lowest. This indicates that fisheries resource management strategies prioritize ecosystems while also considering the economic impact on coastal communities **(Ramadhanty *et al.*, 2022)**. A study by **Ernaningsih *et al.* (2023)** on the sustainability status of grouper on the Spermonde Islands reports the most influential attributes in the economic dimension are fishing business profits and fishery business cooperation. This finding aligns with the results of the economic and technological dimensions (Figs. 3, 5).

The sustainability of grouper in the ecological dimension shows moderate sustainability, with the selectivity of fishing gear and the use of illegal fishing gear being the most influential attributes. The ecological dimension reflects the quality of the environment and resources for fishing activities, which significantly impacts fisheries sustainability **(Chaliluddin *et al.*, 2023)**. Efforts to manage fisheries are expected to provide ecological benefits and promote the sustainability of the surrounding ecosystem. For example, **Liang *et al.* (2014)** reported the significant impact of using environmentally friendly fishing gear on the sustainability of fisheries in China. According to their research, the use of certain fishing gear has led to more selective fish populations, a phenomenon hardly recoverable. **Tang *et al.* (2010)** further emphasized that the type of fishing gear imposes various forms of selection on fish.

Overall, the most influential attributes are from the social dimension, specifically government oversight (8.6732) and compliance with regulations (7.7353), to which the Sasi Law contributes (Fig. 4). This illustrates how the application of these regulations plays a significant role in the sustainability of grouper fisheries. These results show the significant impact of the Sasi Law on the sustainability of grouper fisheries. According to **Ernaningsih *et al.* (2019)**, fishing practices based on open-closed regions and seasons affect population dynamics and exploitation rates of groupers. The Sasi Law is crucial in limiting fishing activities during certain periods. Awareness of the need to manage the marine environment must be increased to ensure sustainability and improve the economy **(Amkieltiela *et al.*, 2022)**.

Furthermore, the processing of fishery products and the type of vessel engine are the most influential attributes in the technological dimension. As the dimension with the lowest sustainability value, this aspect requires urgent attention from the government. Technology has revolutionized fisheries management due to a significant transition in recent years that supports effective and sustainable methods **(Kroodsma *et al.*, 2018)**. Recent research by **Balaji *et al.* (2023)** shows the critical role of technology in fisheries

sustainability. The report reveals that the technologies are revolutionizing aquaculture practices, optimizing data collection, and monitoring fishing operations. Moreover, the application of technology enables better stock assessment and optimizes fishing practices for sustainable yield **(Pinsky *et al.*, 2018)**.

The results of the institutional aspects analysis show the attribute of action against illegal fishing is the most sensitive, along with institutional conflict. **Gunawan (2019)** revealed institutional aspects have a major impact on fishery sustainability and the livelihoods of coastal communities. Currently, Western Papua Province lacks a specific document regarding a grouper fisheries management plan (FMP). Meanwhile, the FMP document for grouper-snapper **(Marine and Fisheries Ministerial Decree Number 123, 2021)** is designed specifically for the overexploited region. However, the fisheries management area (FMA) number 715, which covers the Ayau Islands, is classified as "moderate" for the utilization of reef fish (Decree Document of the Indonesian MFA). Despite this, efforts are needed to implement regulatory policies regarding the management of demersal fisheries in this region at an earlier stage.

CONCLUSION

This study concludes that grouper fisheries sustainability on the Ayau Islands is generally classified as moderate. The economic dimension has the highest sustainability index, while the technological dimension is the lowest. The Sasi Law is included in the attribute of the social dimension, represented by compliance with regulation and government oversight, identified as the most sensitive leverage. This finding demonstrates several critical attributes for ensuring the sustainability of grouper fisheries in Ayau Island, with the Sasi Law playing a significant role in social dimensions. The results suggest more stringent government oversight is necessary to maintain the sustainability of grouper poses.

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