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# Status of Sustainability of the Utilization of the Rabbitfish (*Siganus canaliculatus*) in the Seagrass Ecosystem of the West Coast of South Sulawesi

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**ABSTRACT**

The rabbitfish (*Siganus canaliculatus*) is a type of demersal fish living near the bottom of the water. This fish is often found in coral reef areas and seagrass beds. Currently, the use of the seagrass ecosystem is limited to fishing activities, which, beside the predators, target the rabbitfish broodstock, causing a decrease in the population of the seedlings. Therefore, it is necessary to develop the rearing activities of the rabbitfish seeds in this ecosystem applying technological innovations and using fixed net cages. However, the sustainability status of this rearing business is under question. Hence, the current research was designed to analyze the sustainability status of the rabbitfish utilization activities in the most extensive seagrass ecosystem on the western coast of South Sulawesi in Pangkep and Barru regencies, which is abundant with the seedlings of *Siganus canaliculatus*. To hit this target, the Rapfish method was implemented. Based on the ecological, economic, social, and technological in addition to the institutional and legal dimensions, the sustainability status of the rabbitfish utilization activities at the study site is generally categorized as quite sustainable, with an average ordination value of 58,54.

## INTRODUCTION

The rabbitfish (*Siganus canaliculatus*) belongs to the Siganidae family, and it is a type of demersal fish that lives at the bottom or close to the bottom of the waters. This fish is often found in coral reefs and seagrass beds **(Duffy, 2006; Feryatun*et al*., 2012; Ismail *et al*., 2023)**, both adult fish and their seeds. Currently, the use of seagrass ecosystems **(Rappe, 2010; Firmansyah, 2022)** has not been widely implemented and is still limited to fishing activities, hence with no precise restrictions, chances for overfishing are available.

The West Coast of South Sulawesi, especially in Pangkep and Barru regencies, has an extensive seagrass ecosystem, where many rabbitfish seedlings are found. These fish breeds are vulnerable to being targeted by predators and fishermen due to their small size, resulting in low survival rates to reach adulthood. In addition, the fishing of rabbitfish broodstock by fishermen has also caused a decrease in the population of these fish seedlings in seagrass ecosystems. To overcome this problem, it is necessary to develop aquaculture activities by raising the seeds of rabbitfish, which are abundant in this ecosystem, through technological innovation using fixed net cages installed in seagrass ecosystems and their surroundings **(Rifai *et al*., 2014; Martha *et al*., 2018, Rahman *et al*., 2019)**. The results of this cultivation activity are quite significant, it lasts for 3-4 months. Moreover, the size of fish seedlings can reach 4-5cm, with an average weight of 300-400 grams **(Rauf *et al*., 2017)**.

The sustainability of the cultivation business of rearing the rabbitfish in the seagrass ecosystem **(Latuconsina*et al*., 2013; Syukur, 2016)** hasn't been figured out yet. In an effort to overcome this problem, a comprehensive study was needed on the sustainability status of fish farming businesses, so that the potential of the seagrass ecosystem can be preserved and utilized sustainably.

## MATERIALS AND METHODS

### Research location and time

This research was carried out in Pangkep and Barru regencies (West Coast of South Sulawesi) during May – December 2021. The location selection was based on the presence of seagrass ecosystem resources on the west coast of South Sulawesi.

### Research methods

The methodological approach in this research involved using survey and questionnaire methods, along with direct interviews with respondents. Respondents were determined using a "purposive sampling" technique, namely that the selected respondents were expected to be able to understand and comprehend the problems to be studied. The research framework can be seen in Fig.(1).

Based on the research framework illustrated in Fig. (1), the potential of the rabbitfish on the West Coast of South Sulawesi is quite large, especially in seagrass ecosystems. The rabbitfish breeds are found in this ecosystem, therefore efforts are needed to maintain the population of these seedlings, resulting in a high survival until they reach maturity. One method of cultivation that can be used to maintain the survival of these fish is to use net cages in seagrass beds and their surroundings. To assess the sustainability of this aquaculture business, it is necessary to take into account five aspects in Rapfish analysis, namely ecological, economic, socio-cultural, technological, and institutional aspects.

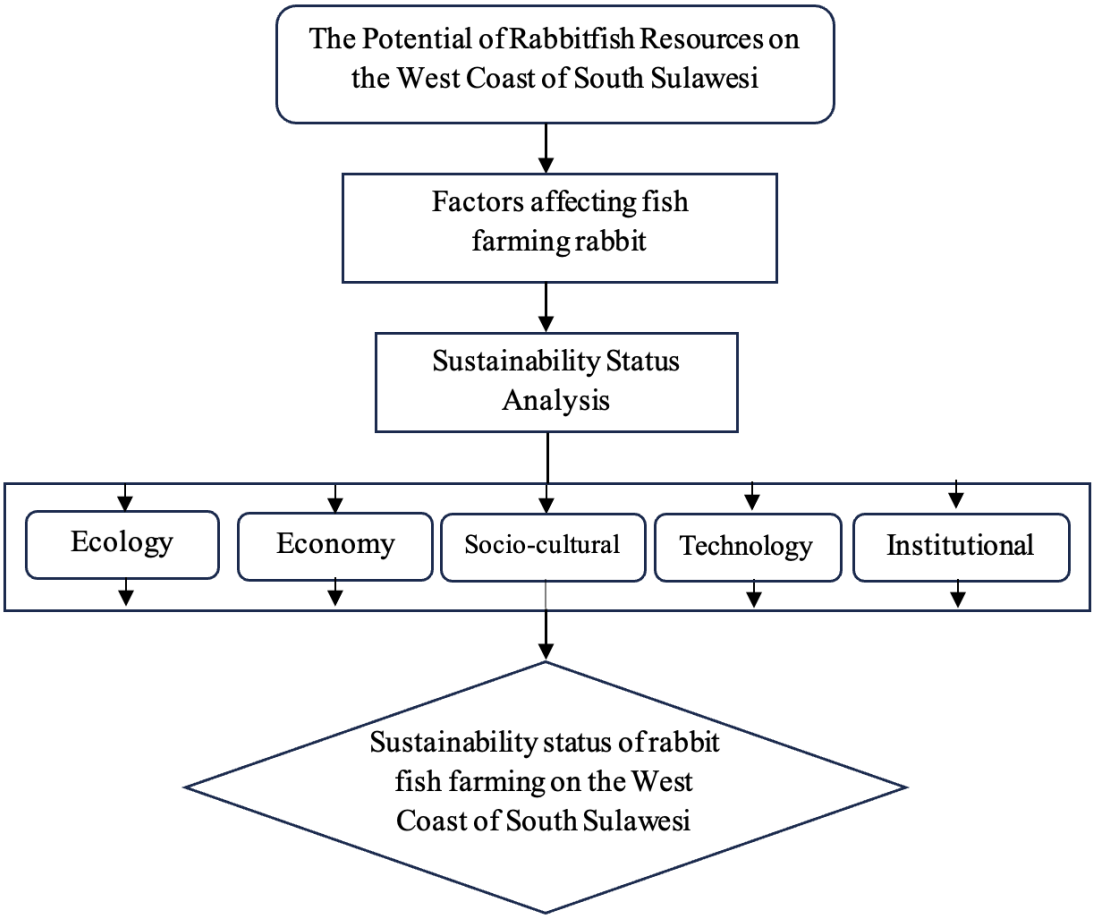


**Fig.1.** Research framework

**Data analysis**

Analysis of the sustainability of rabbitfish farming businesses was carried out using a multidimensional scaling (MDS) approach called RAP-IB which is a modification of the RAP-FISH method used to assess the sustainability status of capture fisheries **(Pitcher & Preikshot, 2001; Kavanagh & Pitcher, 2004; Ali, 2019)**. Sustainability analysis is expressed in the rabbitfish cultivation sustainability index (IKB-IB). The analysis was carried out through several stages:

- The determination of attributes in the rabbitfish farming business includes five main dimensions: ecological, economic, social, technological, and institutional **(Fauzi, 2019)**. Each dimension has several attributes that serve as indicators of sustainability **(Shumka *et al.*, 2023; Yusuf *et al.*, 2023)**. These attributes are taken from previous studies **(Junaidi *et al.*, 2022; Satyawan *et al.*, 2023)**.
- Each attribute is assessed on an ordination scale based on sustainability criteria on each dimension. This assessment uses field observations and secondary data, along with scientific evaluations from scorers **(Tetelepta *et al.*, 2022)**. Therefore, each

attribute is given a score that reflects the level of sustainability in the rabbitfish farming dimension. The score range is 0 to 3, or adjusted according to the special conditions of each attribute. The scale starts from bad (0) to good (3), where bad values reflect the least favorable conditions for sustainable development **(Syam*et al.*, 2023;Youni*set al.*, 2023)**, while good values reflect the most favorable conditions. Between these two value extremes, there are one or more intermediate values, depending on the number of ranks on each attribute **(Fauzi, 2019)**.

- RAPFISH analysis uses the multi-dimensional scaling (MDS) method to determine a single value point that reflects the relative position of seaweed farming. The success of the analysis can be seen from the low stress value, where the stress value that is considered good is less than 25 **(Fauzi, 2019)**.
- In addition to ordination, RAPFISH has an analysis feature called leveraging. Leveraging helps detect dominant attributes by looking at changes in the ordination position (from bad to good), as they are omitted one by one. The leverage value ranges from 2 to 6%, measured through changes in the root mean square (RMS). If the RMS value has a significant increase, it shows that the attribute has a high sensitivity to sustainability **(Fauzi, 2019)**.
- Monte-Carlo analysis is used to find sources of error in data variations **(Fauzi, 2019)**. Errors in RAPFISH can occur due to several things, such as errors in attribute scoring due to lack of information, misunderstanding of attributes or scoring methods, scoring variations due to differences in opinion or judgment from different researchers, data input errors, or the existence of missing data, and high "stress" values of analysis results.

  Preparation of index and sustainability status of rabbitfish cultivation business.The score value of each attribute is analyzed multidimensionally to determine one or several points that reflect the sustainable position of the rabbitfish cultivation business being studied relative to reference points, namely good points and bad points. The resulting index value is an illustration of the current status of the rabbitfish cultivation business. This value is determined by the score value of each attribute in each dimension studied **(Fauzi, 2019)**. Sustainability status categories are presented in Table (1).

**Table 1**. Sustainability status categories for rabbitfish cultivation businesses based on the index value of the analysis results

| Index value | Category |
|---|---|
| ≤ 24,9 | Unsustainable |
| 25 – 49,9 | Less sustainable |
| 50– 74,9 | Quite sustainable |
| >75 | Sustainable |

Source: **Purwaningsih and Santosa (2015)** and **Soejarwo *et al.* (2019)**.

## RESULTS

The assessment of the sustainability of the rabbitfish farming on the West Coast of South Sulawesi was carried out using the multi dimensionalscaling (MDS) approach using the Rap-Fish Tools, where this method was initially used to assess the sustainability status of capture fisheries **(Pitcher & Preikshot, 2001; El Kifa*et al.*, 2023)**. The results of this sustainability analysis are expressed in a business sustainability index which reflects the sustainability status of the implementation of the rabbitfish cultivation business development program based on existing conditions. The sustainable index value for each dimension of sustainability (ecological, economic, social, technological and institutional) is determined by providing a scoring value for each dimension which is the result of the assessment and opinion of the expert team **(Fauzi, 2019; Hidayah *et al.*, 2020; Hamed*et al.*, 2023)**. This sustainability analysis uses the Rapfish technique with the MDS method with five various dimensions, namely: ecological, economical, socio-cultural, technological, legal, and institutional.

The ordination results of the ecological dimension (Fig.2) on the horizontal axis show the difference in values from bad (0%) to good (100%) ordination results for the sustainability of the rabbitfish farming business, and the vertical axis shows the difference from the mix of evaluated attribute scores. The ordination analysis shows that ecological sustainability lies between bad and good. Moreover, the ordination analysis resulted in a quadratic correlation (R2) of 95.25% and a stress value (S) of 15.57%.

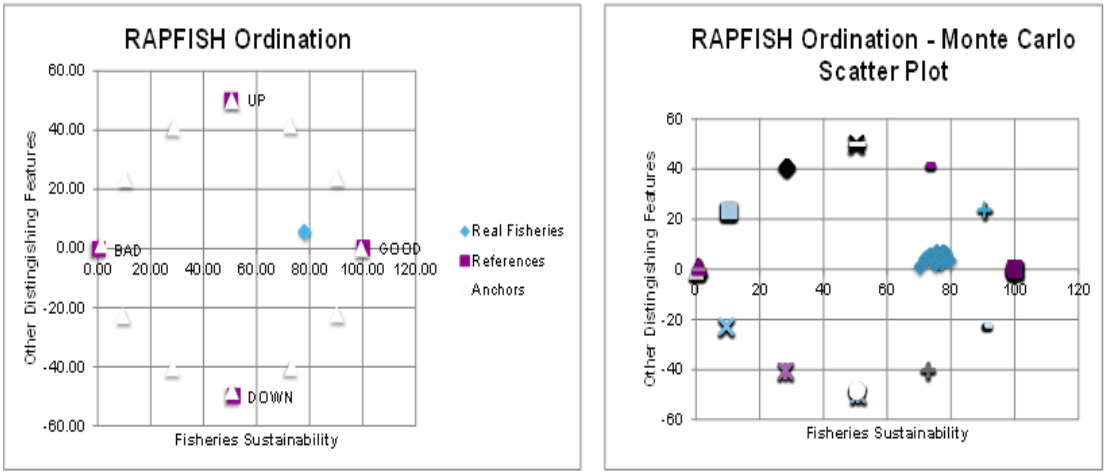


**Fig. 2.** Results of the ecological dimension ordination analysis

To see each attribute as a leverage factor on the sustainability index value in the ecological dimension, a leverage analysis was carried out (Fig.3). The leverage analysis aims to detect the sensitivity of attributes in a dimension **(Alder *et al.*, 2000; Fauzi, 2019)**. The greater the leverage value, the more sensitive the attribute, meaning that the greater the change in the attribute, the greater the impact on the level of sustainability, hence it needs attention. The leverage value for each attribute is as follows: (1) seed size

= 6.29; (2) distribution = 4.39 ; (3) seagrass meadow conditions = 5.38; (4) number of catches = 10.17; (5) catch size = 4.61; (6) utilization rate = 3.67.

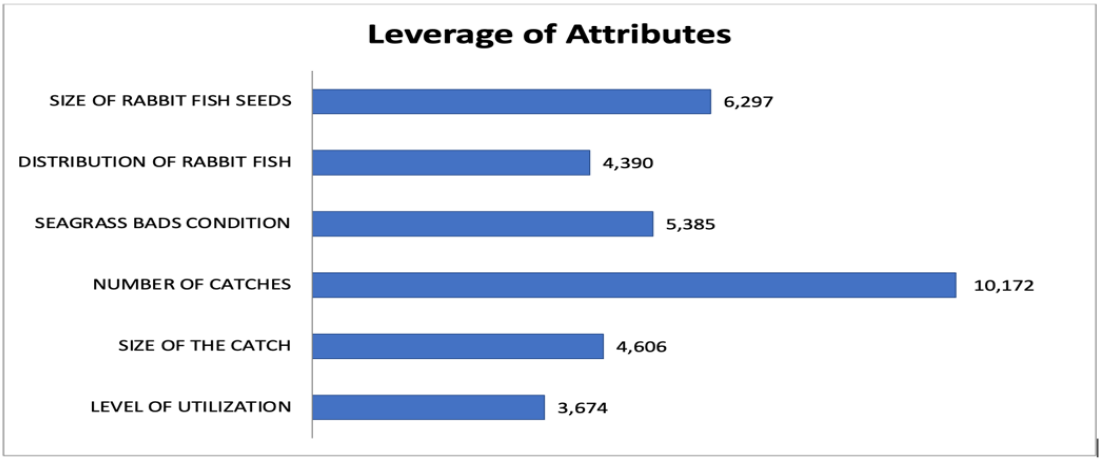


**Fig.3.** Results of the ecological dimension leverage analysis

The result of the ordination of the economic dimension (Fig.4), resulted in a quadratic correlation (R2) of 96.25% and a stress value (S) of 14.66%. This value indicates that all these attributes relate to the economic dimension. The stress value reflects the goodness of fit in multi-dimensional scalling (MDS) analysis, which indicates a measure of how precisely the configuration of a point can reflect the original data. A low stress value indicates good fit, while a high stress value indicates a good condition. In multi dimensionalscalling (MDS) analysis, a good stress value is less than 25% **(Fauzi&Anna, 2005)**.

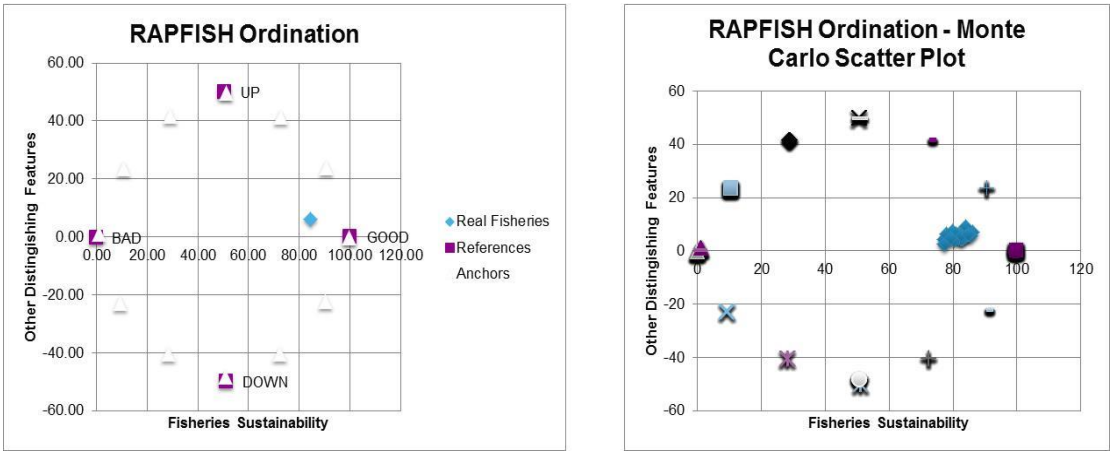


**Fig.4.** Results of the economic dimension ordination analysis

The leverage value of each attribute is as follows (Fig.5): (1) The rabbitfish business profit = 3.03; (2) GDP contribution of fisheries sector = 3.66; (3) market = 3.70; (4) income relative to UMR = 3.88; (5) other income = 2.79; (6) fisheries business cooperation = 7.51.

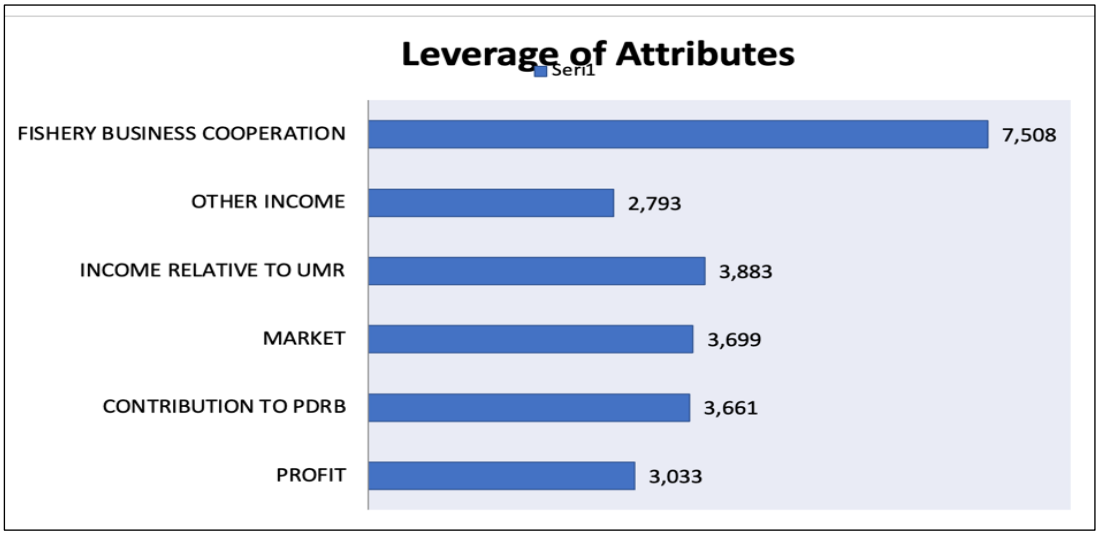


**Fig.5.** Results of the economic dimension leverage analysis

The results of the ordination of the socio-cultural dimension (Fig.6) resulted in a quadratic correlation (R2) of 92.55% and stress value (S) of 14.36 %. This value indicates that all attributes are related to the socio-cultural dimension.

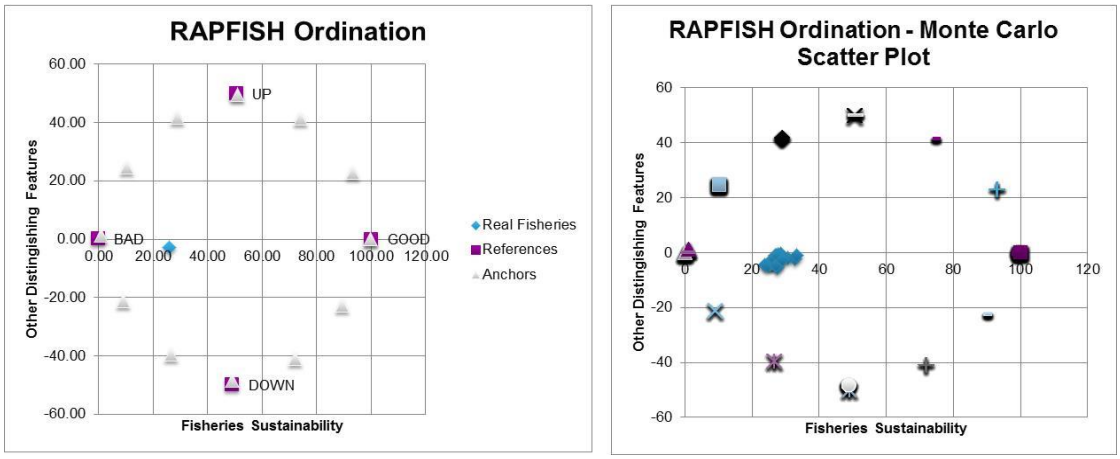


**Fig.6.** Results of the social dimension ordination analysis

The leverage value for each attribute (Fig. 7) is as follows: (1) conflict = 1.17; (2) local wisdom = 6.00; (3) knowledge about the environment = 8.26; (4) involvement of family members = 6.79; (5) frequency of meetings between residents = 9.26; (6) education level = 1.81.

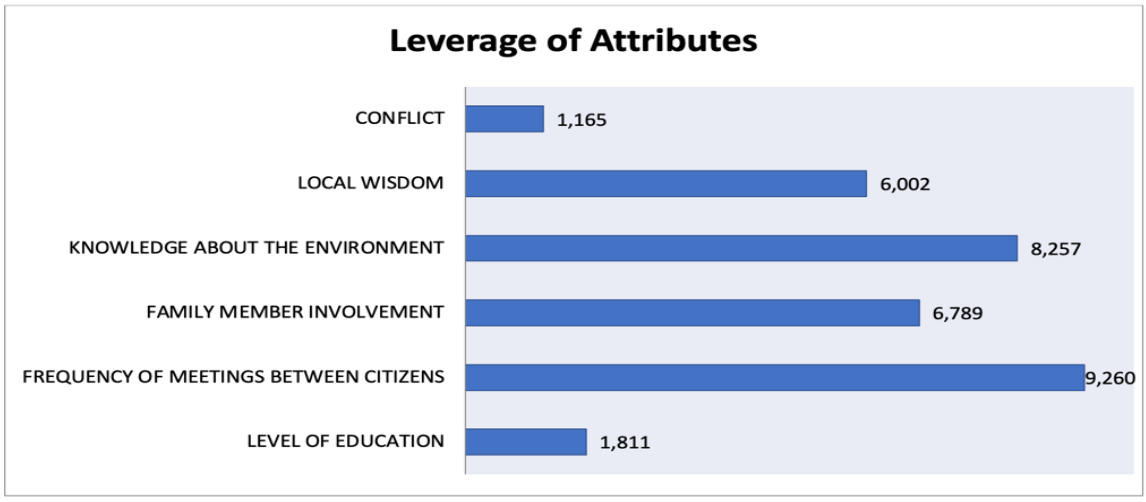


**Fig.7.** Results of the leverage analysis of socio-cultural dimensions

The ordination results from the technological dimensions are presented in Fig. (8). The ordination analysis shows that sustainable technologylies between bad and good. Moreover, the ordination analysis with two iterations yielded a quadratic correlation (R2) of 93.65% and a stress value (S) of 14.55%. This value indicates that all these attributes relate to the technology dimension.

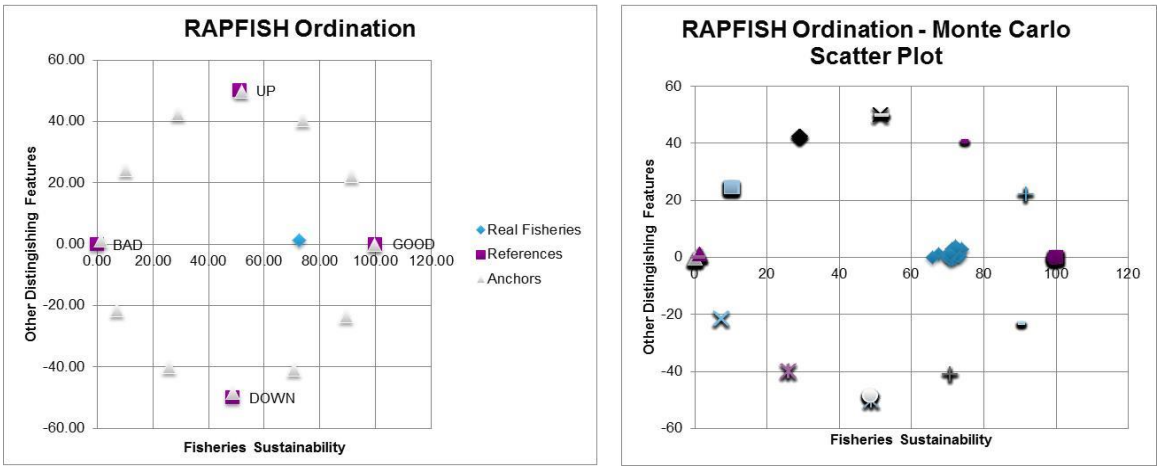


**Fig. 8.** Results of the technological dimension ordination analysis

The leverage value for each attribute (Fig. 9) is as follows: (1) processing before sales = 0.96; (2) negative influence of fishing gear = 5.38; (3) nature and type of fishing gear = 7.48; (4) availability and mastery of information = 6.67; (5) technology utilization = 7.59; (6) facilities and infrastructure = 4.07.

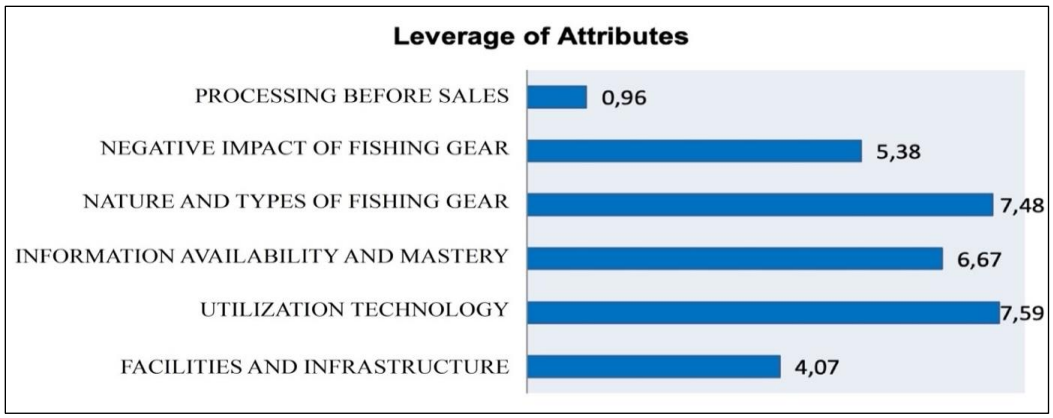


**Fig. 9.** Results of the technological dimension leverage analysis

The ordination analysis (Fig.10) shows that the institutional and legal sustainability lies between bad and good. Moreover, the ordination analysis with 2 (two) iterations resulted in a quadratic correlation (R2) of 94.28% and a stress value (S) of 14.24%. This value indicates how much the results of this analysis can be trusted. The closer to 100% the R2 value, the more it is believed that all attributes are related to the legal and institutional dimensions.

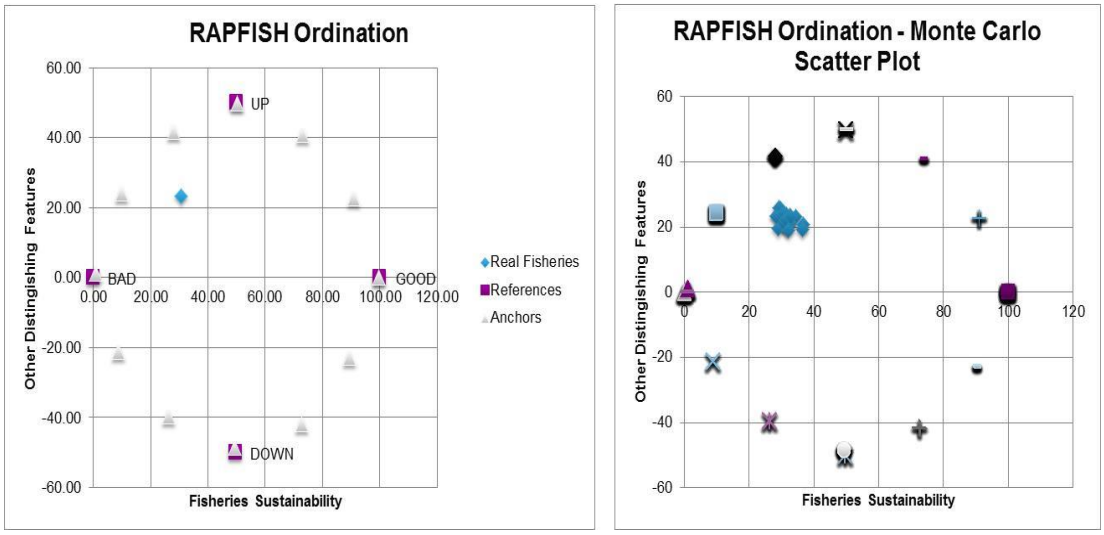


**Fig.10.** Results of the legal and institutional dimension ordination analysis

The leverage value for each attribute is as follows: (1) fishing access restrictions = 6.90; (2) Financial institutions = 7.36; (3) involvement in decision making = 0.56; (4) law enforcement = 7.70; (5) user group = 11.49; (6) formal rules= 7.94 (Fig. 11).

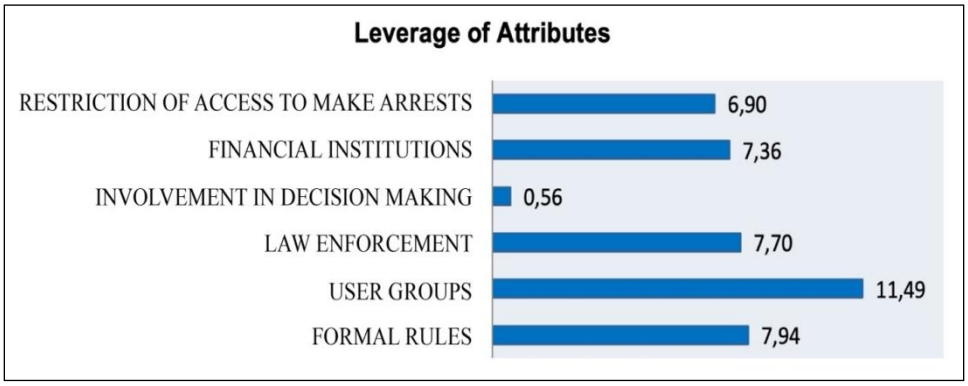


**Fig. 11.** Results of the leverage analysis of legal and institutional dimensions.

The results of MDS and Monte Carlo analysis are presented in Table (2).

**Table 2.** Results of the MDS and Monte Carlo analysis

| **Index status** | **Status** | **Result** | |
|---|---|---|---|
| | | **MDS** | **Monte Carlo** |
| 1. Ecology | Sustainable | 78.80 | 77.09 |
| 2. Economy | Sustainable | 84.44 | 83.87 |
| 3. Social-culture | Less sustainable | 26.00 | 27.52 |
| 4. Technology | Quite sustainable | 72.75 | 71.59 |
| 5. Law and Institutions | Less sustainable | 30.72 | 31.40 |
| Average amount | Quite sustainable | **58.54** | **58.29** |

Fig. (12) shows that community activities in terms of ecological, economic and technological dimensions are sufficient to support the sustainability of the rabbitfish cultivation in seagrass ecosystems in the coastal areas of Pangkep and Barru regencies. Meanwhile, the socio-cultural, institutional and legal dimensions need to receive attention from the government, both district/city, provincial and central levels to ensure the sustainability of the rabbitfish cultivation.

The average number in Table (2) shows that the sustainability status of the rabbitfish farming business on the the West Coast of South Sulawesi is quite sustainable, with a MDS value of 58.54.

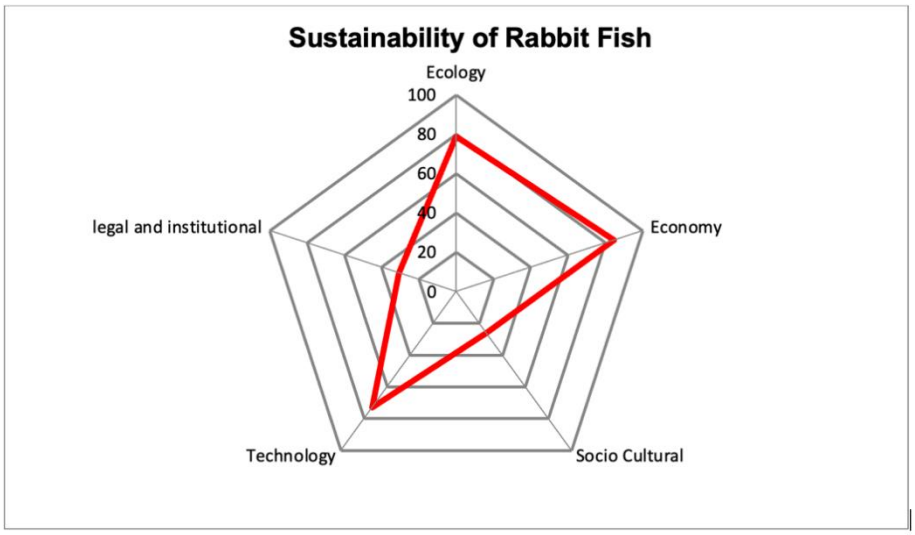


**Fig.12.** Diagram of the sustainability levels for the rabbitfish cultivation

## DISCUSSION

### 1. Ecological dimension sustainability index

The RAPFISH analysis confirmed by MONTE CARLO (Fig. 2) shows that the ecological dimension in the rabbitfish farming business obtained a sustainability status value of 78.80. These results illustrate that from an ecological perspective, the effort is included in the sustainable category with a score above 75.

The results of the leverage analysis of ecological dimensions (Fig. 3) illustrate that the three most sensitive attributes are catch count (10.17), seedling size (6.29), and seagrass meadow condition (5.38). That is, in formulating policies to improve the sustainability status of the ecological dimension, it is necessary to pay attention and consider these three attributes.

### 2. Economic dimension sustainability index

The RAPFISH analysis confirmed by MONTE CARLO (Fig. 4) shows that the economic dimension in the rabbitfish farming business obtained a sustainability status value of 84.44. These results illustrate that from an economic perspective, the business is included in the sustainable category with a score above 75.

The results of the leverageanalysis of the economic dimension (Fig.5) illustrate that the three most sensitive attributes are fisheries business cooperation (7.51), income relative to UMR (Regional Minimum Wage) (3.88), and market (3.70). That is, in formulating policies to improve the sustainability status of the economic dimension, it is necessary to pay attention and consider these three attributes.

**3. Socio-cultural dimension sustainability index**

The RAPFISH analysis confirmed by MONTE CARLO (Fig. 6) shows that the socio-cultural dimension in the rabbitfish farming business obtained a sustainability status value of 26.00. These results illustrate that from a socio-cultural perspective, the business is included in the less sustainable category with a score below 50.

The results of leverage analysis of the socio-cultural dimension (Fig. 7) illustrate that the three most sensitive attributes are the frequency of meetings between citizens (9.26), knowledge about the environment (8.26), and the involvement of family members (6.79). That is, in formulating policies to improve the sustainability status of the socio-cultural dimension, it is necessary to pay attention and consider these three attributes.

**4. Technology dimension sustainability index**

The RAPFISH analysis confirmed by MONTE CARLO (Fig. 8) shows that the technological dimension in the rabbitfish farming business obtained a sustainability status value of 72.75. These results illustrate that from a technological perspective, the business is included in the category of quite sustainable with a score below 75.

The results of the leverageanalysis of the technology dimension (Fig. 9) illustrate that the three most sensitive attributes are utilization technology (7.59), nature and type of fishing gear (7.48), and availability and mastery of information (6.67). That is, in formulating policies to improve the sustainability status of the technological dimension, it is necessary to pay attention and consider these three attributes.

**5. Sustainability index for legal and istitutional dimensions**

The RAPFISH analysis confirmed by MONTE CARLO (Fig.10) shows that the legal and institutional dimensions in the rabbitfish farming business obtained a sustainability status value of 26.00. These results illustrate that from the perspective of legal and institutional dimensions, the business is included in the less sustainable category with a score below 50.

The results of leverageanalysis of legal and institutional dimensions (Fig. 11) illustrate that the three most sensitive attributes are the frequency of meetings between citizens (9.26), knowledge of the environment (8.26), and involvement of family members (6.79). That is, in formulating policies to improve the status of sustainability from the legal and institutional dimensions, it is necessary to pay attention and consider these three attributes.

**MDS and Monte Carlo analysis**

The Monte Carlo simulation aims to see the level of disturbance to the ordination value **(Nababan *et al.*, 2017; Fauzi, 2019)**. By carrying out 30 iterations, the Monte Carlo analysis using a scatter plot shows that the ordination value is quite stable, therefore it is believed that the ordination value has a fairly high level of confidence. Additionally, the scatter plot results, the Monte Carlo and MDS simulations are shown in Table (2) and Fig.(12).

## CONCLUSION

Based on the description of the results and previous discussion, it can be concluded that:

- The rabbitfish cultivation (rearing) in the seagrass ecosystem has the potential to be developed as an alternative livelihood for fishermen on the West Coast of South Sulawesi.
- The sustainability status of the rabbitfish cultivation business in the west coastal region of South Sulawesi in terms of the ecological dimension with an ordination value of 78.80 is a good sustainability level category, the economic dimension with an ordination value of 84.44 is a good sustainability level category, the socio-cultural dimension with an ordination value 26.00 is a sufficient level of sustainability category, the technology dimension with an ordination value of 72.75 is a sufficient level of sustainability, the institutional and legal dimensions with an ordination value of 30.72 are a sufficient level of sustainability.
- The sustainability status of the rabbitfish utilization activities in the West Coastal region of South Sulawesi is generally categorized as quite sustainable, with an average ordination value of 58.54.

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