Sustainability of Lobster (*Panulirus* spp.) and Baby Lobster (*Puerulus*) in Pangandaran District West Java Province

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ABSTRACT

Lobster is one of Indonesia's marine fisheries resources that has a high selling value. The level of lobster utilization in southern Java Island in 2022 is over exploited. Pangandaran Regency is one of the potential lobster fisheries centers, but the population and catches continue to decline every year. This study aimed to assess the sustainability index of lobster and baby lobster in Pangandaran Regency. The study was conducted from January to February 2024 in Madasari, Legokjawa, Batukaras, Muaragatah, Pangandaran Beach and Majingklak. Data were obtained through interviews with fishermen. The sampling method to determine lobster fishermen respondents was purposive sampling while baby lobster fishermen respondents used the snowball sampling method. Sustainability index analysis using Multi-Dimensional Scaling (MDS) Rapfish. The results showed that the lobster sustainability index was 53.91 with a fairly sustainable category while the baby lobster sustainability index was 47.57 with a less sustainable category. Social and institutional dimensions are the most influential dimensions in the sustainability of lobster and baby lobster. The sustainability level of baby lobsters (*Puerulus*) is lower than that of lobsters (*Panulirus* spp.) because baby lobsters are exploited more than lobsters. This will cause a decline in lobster stocks in the future. The practice of exploiting baby lobsters must be given special attention, starting from stock calculations, allowable catch amounts, habitat conditions, and supervision of fishing practices.

INTRODUCTION

Lobsters (*Panulirus* spp.) are a group of crustaceans that are important fishery commodities for consumption and export that are distributed in Western Indo-Pacific waters including the southern waters of Java. Lobster is one of Indonesia's marine fisheries resources that has a high selling value (**Hilyana *et al*., 2021;Tirtadanu *et al*.,**

2021; Manik *et al.,* 2024). In the fisheries sector, lobster is one of the most valuable export products **(Nguyen *et al.,* 2017; Maskun *et al.,* 2020; Widhiastika *et al.,* 2024)**. High global demand and limited stocks lead to the high selling value of lobster fisheries **(Maskun *et al.,* 2020; Manik *et al.,* 2024)**. Lobster is a marine biota whose habitat is in coral areas **(Butler & Kitnzing 2016; Setyanto *et al.,* 2019; Nandini *et al.,* 2023)**. Lobster species found in Indonesia are ornate spiny lobster (*Panulirus ornatus*), green scalloped rock lobster (*Panulirus pomarus*), rock lobster (*Panulirus penicillatus*), spiny lobsters (*Panulirus longipes*), painted spiny lobster (*Panulirus versicolor*) and pakistan lobster (*Panulirus polyphagus*).

The level of lobster utilization in southern Java (WPPNRI 573) in 2017 was fully exploited **(KKP, 2017)**. Five years later KEPMEN-KP No. 19 of 2022 stated that the utilization rate of lobster resources in 7 out of 11 WPPNRI (Fisheries Management Areas of the Republic of Indonesia) was over exploited. WPPNRI 573 is the area with the highest level of lobster resource utilization that is over exploited (E= 2.0). Over exploited lobster resources are caused by overfishing **(Irwani *et al.,* 2019; Manik *et al.,* 2023)**. Overfishing occurs because the utilization of lobster resources for socioeconomic interests of the community is more dominant than other aspects **(Cheung & Sumaila, 2015; Mardyani *et al.,* 2020)**.

The Ministry of Maritime Affairs and Fisheries of the Republic of Indonesia (KKP) has issued regulations on the management of lobsters (*Panulirus* spp.) which are contained in Permen KP No. 7 of 2024 concerning Management of lobsters (*Panulirus* spp.), crabs (*Scylla* spp.) and blue crab (*Portunus* spp.). Lobsters that can be caught are not in egg-laying condition, a minimum size of 150 grams per tail and a group size above 6cm for green scalloped rock lobster (*Panulirus pomarus*), rock lobster (*Panulirus penicillatus*), spiny lobsters (Panulirus longipes), and pakistan lobster (*Panulirus polyphagus*). Other lobster species may be caught without laying eggs and with a carapace length above 8cm or weight above 200 grams per fish. The prohibition of catching lobster laying eggs and limiting the size of lobster fishing is expected to encourage the recovery of lobster resources in nature so that their utilization is sustainable **(KKP, 2024)**. **Forsyth and Johnson (2014)** said that institutional intervention is needed to regulate exploitative behavior and empowerment in policy making at the local level where environmental degradation is occurring.

Pangandaran Regency is one of the potential lobster fisheries centers **(Rahman *et al.,* 2024)**. Pangandaran Regency has a sea area of 67,340 Ha **(BPS Pangandaran, 2024)** and is included in WPPNRI 573. Pangandaran Regency has a craggy coastal area which is a characteristic of waters that supports lobster habitat (*Panulirus* spp). The lobster fishing area in Pangandaran stretches from the waters of Legokjawa to the area bordering Cilacap Regency **(Rahman *et al.,* 2024)**. Lobster fisheries in Pangandaran are categorized as small-scale fisheries **(Nurfiarini & Wijaya, 2019)**. Small-scale fisheries are generally described as a group of people with minimum income, marginalized and

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vulnerable to social and economic shocks, who therefore require some level of social and economic support and protection **(Halim *et al.*, 2018)**. Small-scale fisheries are threatened by declining catches, increasing environmental degradation and overcapacity **(Gough *et al.*, 2020; Rizal *et al.*, 2024)**.

Baby lobster management is regulated in the regulation of PERMEN KP Number 7 of 2024. Regulation The exploitation of baby lobster for cultivation is allowed as long as it has a permit with a predetermined quota. Then, the lowest baby lobsters price at the fishermen level is Rp. 8,500 which is regulated in KEPMEN KP Number 24 of 2024 concerning the lowest benchmark price of baby lobster. In addition, to maintain the sustainability of baby lobster, the Ministry of Maritime Affairs and Fisheries makes regulations through KEPMEN KP Number 28 of 2024 concerning the estimated potential, the number of allowable catches, and the quota for catching baby lobster (*puerulus*). The estimated potential of baby lobster in WPPNRI 573 is 61,379,474 with a total allowable catch of 55,241,527.

Based on the sequence of problems above, the authors conducted research on the sustainability status of lobster fisheries including adult and baby lobsters in the waters of Pangandaran Regency. The status and strategy of fisheries sustainability is important to know since it serves as a formulation in making sustainable policies for sustainable lobster fisheries to realize community welfare **(Lynch *et al.*, 2016)**. The management of marine and fisheries resources requires comprehensive, integrated and targeted policies, considering that the area has problems, potential and unique characteristics. The sustainability of capture fisheries is determined by the interaction of several important aspects (dimensions) such as ecological, technological, social, economic and institutional dimensions **(FAO Fishery Resources Division, 1999a; Charles, 2001; Nababan *et al.* 2007)**.

MATERIALS AND METHODS

Location and time of study

This research was conducted from January to March 2025 in Pangandaran Regency West Java Province. Research on the sustainability status of lobster (*Panulirus* spp) and baby lobster (*Puerulus*) was conducted in several locations of lobster landing points, namely Madasari, Legokjawa, Batukaras, Muaragatah, Pangandaran Beach and Majingklak. Then, the research was conducted at the Pangandaran Marine Fisheries and Food Security Office, Pangandaran Marine and Fisheries Resources Monitoring and Cikidang Fish Landing Base to obtain secondary data. The map of the research location is shown in Fig. (1).
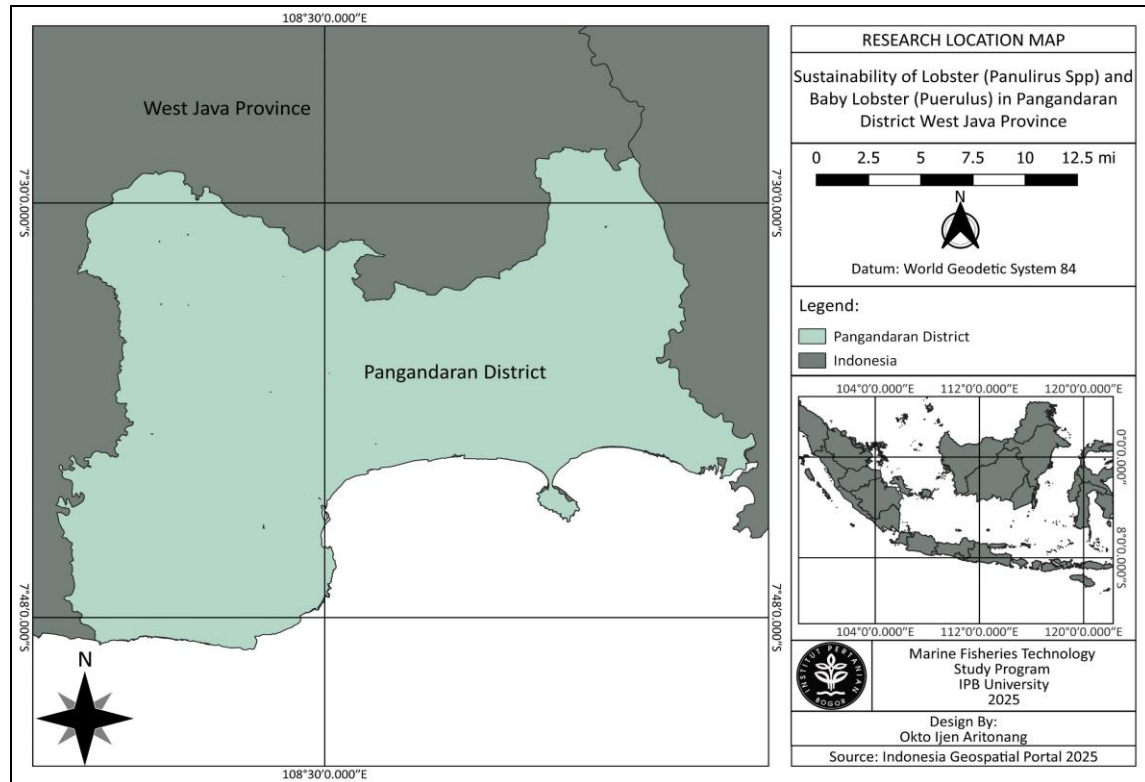
Fig. 1. Map of the research location

Research tools and materials

The tools used were rapfish questionnaires, Arcgis 10.8 software, Microsoft Excel 365 and Microsoft Word 365. While the materials needed were lobster and statistical data on lobster fishing units.

Method of collecting data

The assessment of lobster sustainability status was reviewed from several aspects, namely ecological, technological, economic, social and institutional aspects. The data required included primary data by conducting interviews using rapfish questionnaires with fishermen respondents. The sampling method used to determine lobster fishermen respondents is purposive sampling with the criteria that fishermen use as trammel net fishing gear. Meanwhile, baby lobster fishermen respondents were carried out using the snowball sampling method. The number of lobster fishermen found during the research was 18 fishermen. While the number of lobster fishermen respondents was calculated using the Slovin formula:

$$n = \frac{N}{1 + N.e^2}$$

Description:
n= Sample size
N= Total population
e= Critical value or error tolerance limit

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The total population of trammel net fishermen in Pangandaran Regency is 339 people. The error tolerance limit used is e = 10% (0.1) based on the assumption that the population is in the large number category. Based on the calculation of the Slovin formula, the number of respondents was 77 people and the researchers rounded up to 80 people.

Data analysis

The sustainability level of the lobster fishery in Pangandaran Regency was analyzed using Rapfish technique. Rapfish is used to evaluate the sustainability index of small-scale fisheries (**Preikshot *et al*., 1998**) and commercial fisheries (**Murillas *et al*., 2008**). This sustainability analysis technique uses the principles of Multi Criteria Analysis (MCA) by relying on an algorithm called the MDS algorithm (**Fauzi & Anna, 2005**). Multi-Dimensional Scaling (MDS) is a statistical analysis technique that performs multidimensional transformation (**Fauzi & Anna, 2002; Kavanagh & Pitcher, 2004; Budiharsono, 2007**).

The dimensions used to assess the sustainability status of lobster and lobster clear fry refer to the study of **Nababan *et al*. (2007)**, who explain that to obtain a comprehensive analysis of the sustainability status of fisheries resource management, at least five aspects must be reviewed, namely (1) ecological; (2) economic; (3) technological; (4) social and (5) institutional. Furthermore, the attributes in each dimension are determined based on references from the FAO-Code of Conduct, EAFM (Ecological Approach of Fisheries Management) and relevant previous research sources.

In the MDS with RAPFISH, each dimension (ecological, technological, economic, social and institutional) is analyzed separately. As reference points for evaluating the status of the fishery, "good" and "bad" sustainability scores are assigned to each dimension (**Pitcher *et al*., 1998; Pitcher & Preikshot, 2001**). The ordination technique of point distances in the MDS is based on the Euclidian distance (d), where for a two-dimensional space (x and y), d is calculated by the following formula (**Fauzy & Anna, 2002; Wickelmaier, 2003**):

$$d = \sqrt{\{(x1 - x2)^2 + (y1 - y2)^2\}}$$

The result of the MDS analysis is an ordination plot on a two-dimensional axis. The horizontal axis shows the status of fisheries sustainability (from 0% to 100%). After the MDS analysis, a sensitivity analysis or leverage analysis was conducted in RAPFISH. The result of this analysis is the percentage change in root mean square (RMS) if each attribute is removed from the ordination (**Kavanagh & Pitcher, 2004**). In other words, the sensitivity of an attribute is assessed based on the percentage change in RMS between ordination with the attribute included and without the attribute (**Fauzy & Anna, 2002**). The RMS value is calculated using the formula of **Sweking *et al*. (2014)**:

$$\text{RMS} = \sqrt{\frac{\sum_1^n \{V(i) - V\}^2}{n}}$$

Where, V(i) is the MDS value after rotation, and V is the median MDS value after rotation. Afterward, the MDS results were validated using monte carlo analysis with 100 repetitions, based on the assumption of normally distributed errors with a 95% confidence interval set at 20% of the maximum value of each attribute **(Kavanagh & Pitcher, 2004)**. Goodness of fit was evaluated based on Kurskal's stress and the coefficient of determination (R2) **(Kavanagh & Pitcher, 2004)**. An acceptable stress value is less than 0.25 **(Pitcher & Preikshot 2001)** and the coefficient of determination (R2) is close to 1. Stress values were calculated using the following formula **(Analytictech, 2016)**:

$$\text{Stress} = \sqrt{\frac{\sum (f(p)-d)^2}{d^2}}$$

Where, f(p) is a function of the input data and d is the Euclidian distance. All of the above analyses were conducted using the RAPFISH program package which is an "add-in" to Microsoft's Excel **(Kavanagh & Pitcher, 2004)** downloaded from www.RAPFISH.org.

Table 1. Sustainability index category

No	Index value	Sustainability Category
1	0 – 25	Bad (Unsustainable)
2	26 – 50	Less (Less Sustainable)
3	51 – 75	Fair (Moderately Sustainable)
4	76 – 100	Good (Very Sustainable)

Source: **Pitcher (1999)**

RESULTS AND DISCUSSION

Lobster sustainability status (*Panulirus* spp)

Ecological dimension

The results of the analysis show that the ecological dimension sustainability index is 63.28 with a fairly sustainable category. The ordination graph of the ecological dimension sustainability index is shown in Fig. (2).
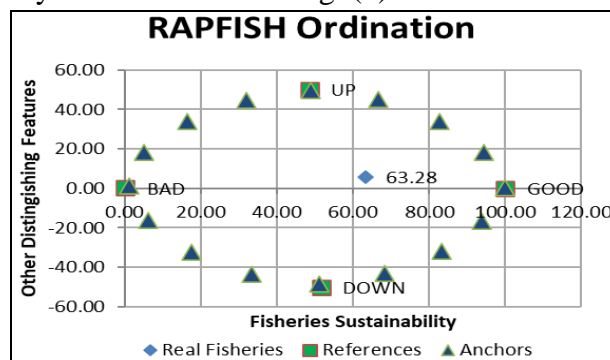

Fig. 2. Ecological dimension sustainability index

Based on the results of the leverage analysis (Fig. 3), there are 3 attributes that stand out and show that these attributes are indicators that are sensitive to the value of the ecological dimension sustainability index. These attributes are the range of lobster migration, changes in lobster trophic level and the size of lobster caught. Lobster migration is caused by climate change and habitat degradation that occurs due to loss of seagrass and seaweed which can disrupt ecological balance and increase food competition among marine species including lobsters **(Sabino *et al*., 2021)**. Lobsters in Pangandaran Regency migrate 2-3 times a year. This happens because the Pangandaran coast is extremely vulnerable to erosion **(Dhiauddin *et al*., 2019)** and human activities that cause water pollution **(Dewi *et al*., 2020)**.

Leverage of Attributes

Attribute	Value
Captured species	2.82
By Catch	3.64
Capture size before Lm	4.41
Size of Lobster Caught	4.56
Migration Range	5.74
Changes in Trophic Levels	5.38
Diversity Recruitment	3.94
Exploitation Status	0.47

Root Mean Square Change in Ordination when Selected Attribute Removed (on Sustainability scale 0 to 100)
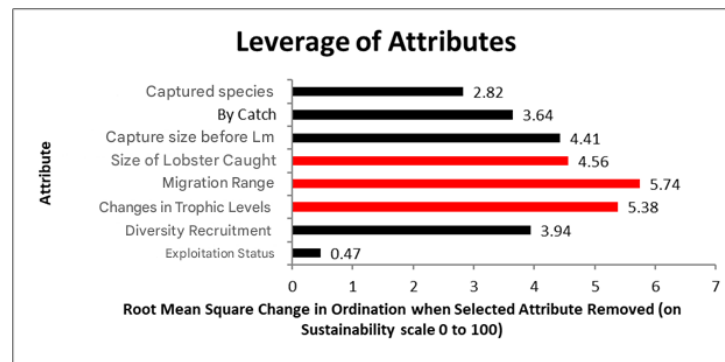
Fig. 3. Ecological dimension leverage analysis

When trophic lobster is in a middle level position that acts as a secondary consumer **(Almohdar & Souisa, 2018; Day *et al*., 2022)**. Lobsters in Indonesia generally prey on various food sources, namely molluscs, crustaceans, detritus and plants **(Wijaya *et al*., 2018)**. The size of lobsters caught in the past five years has experienced gradual changes. According to information from fishermen, the length and weight of lobsters are getting smaller every year, so that lobster catches are often below the size determined by KKP Regulation No. 07 of 2024. Lobsters under the size caught by fishermen are never released back into the sea. This is because fishermen do not want to experience losses because the capital for fishing includes fuel, engine maintenance costs, fishing gear maintenance, boat maintenance and food.

Technology dimension

The results of the analysis show that the sustainability index of the lobster technology dimension is 65.19 with a fairly sustainable category. The ordination graph of the technology dimension sustainability index is shown in Fig. (4)
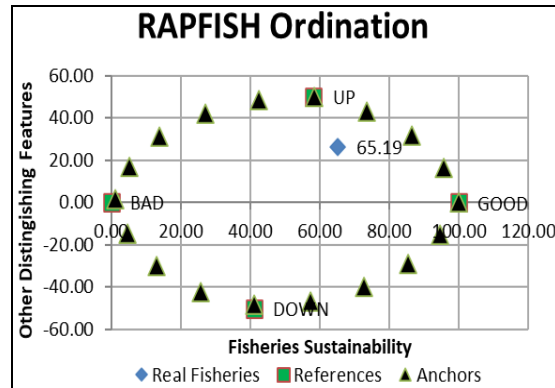
Fig. 4. Technology dimension sustainability index

Based on the leverage analysis (Fig. 5), there are three attributes sensitive to the sustainability dimension of lobster technology, namely pre-sale processing, fish landing sites and length of fishing. Lobster fishermen in Pangandaran District do not perform processing before the lobster is sold. Pre-sale processing of lobster is done to improve the quality and selling value of lobster. Lobster pre-sale processing activities include quick freezing immediately after the lobster dies to maintain the freshness and flavor of the lobster **(Bochun *et al.*, 2018)**, thorough cleaning lobsters to prevent contamination on the surface of the lobster **(Zhongyue, 2019)**, and sorting lobsters based on size and quality **(Johansyah *et al.*, 2022)**.
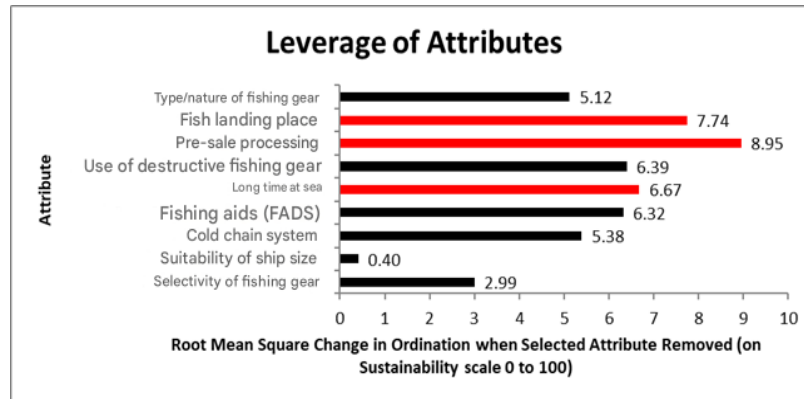

Fig. 5. Technology dimension leverage analysis

Lobster landing sites are scattered in several locations, namely TPI Batukaras, TPI Madasari, TPI Legokjawa, TPI Pangandaran and TPI Majingklak. Non-centralized lobster landing causes inaccurate data related to catches. In addition, numerous fishermen do not land their lobster catch at the designated fish landing site because the captured lobster is below the required size. Lobsters under the size will be sold behind closed doors at a lower price to collectors. This has resulted in the Pangandaran Regency Marine Fisheries and Food Security Agency lacking accurate data related to lobster management. Inaccurate data causes difficulties in the regulatory process **(Hungtington *et al.*, 2015; Clegg *et al.*, 2021)**. Fishermen in Pangandaran district conduct lobster fishing with the

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duration of one day fishing. One day fishing has several good impacts such as the quality of lobster caught is still in fresh status thus increasing the price and profitability of the catch **(Sidiq *et al*., 2023)**, reduced impact on the environment including reduced fuel consumption and lower emissions **(Cooke *et al*., 2024)**, reduced overfishing pressure **(Melnychuk *et al*., 2024)**.

Economic dimension

The results of the analysis show that the sustainability index of the economic dimension of lobster is 67.85 with a fairly sustainable category. Rapfish sustainability index ordination graph is shown in Fig. (6).
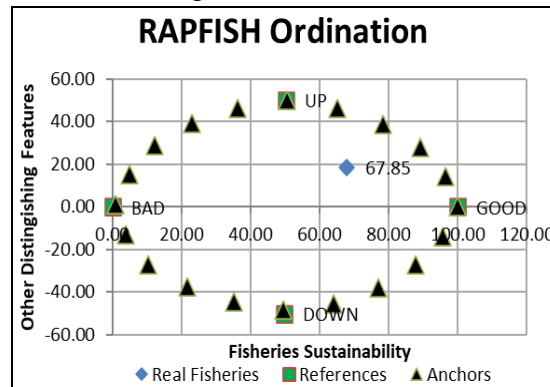

Fig. 6. Economic dimension sustainability index

Based on the leverage analysis (Fig. 7), there are three attributes that are sensitive to the economic dimension of sustainability, namely employment, average income and government subsidies. The status of lobster fishers in Pangandaran district is predominantly informal due to the lack of formal contracts and social security benefits. The informal nature of employment in the Indonesian fishing industry is largely due to traditional practices and economic strategies used by businesses to minimize costs and maximize profits **(Jones *et al*., 2019)**. Lobster fishers in Pangandaran district should have formal status in order to obtain formal employment contracts **(Ablaza *et al*. 2021)**, social security benefits and improve the legal protection of fishers' rights as well as integrate their perspectives into the policy-making process **(Kaya & Sajriawati, 2023)**.
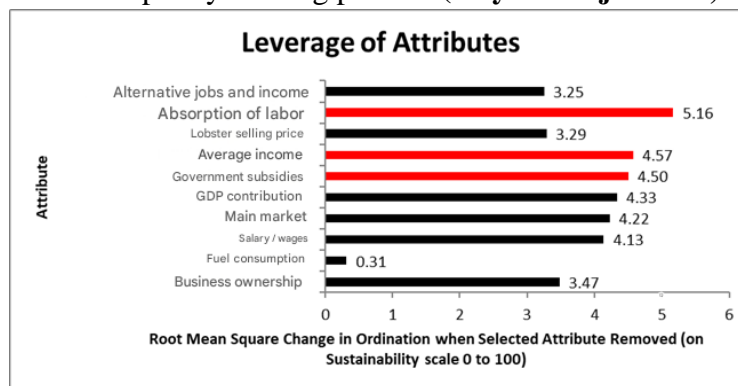

Fig. 7. Economic dimension leverage analysis

The average income of lobster fishers in Pangandaran Regency is above the Pangandaran Regency minimum wage of IDR 2,221,724. Economic factors and poverty are significant contributors to overfishing **(Wijaya & Fauzie, 2020)**. It is therefore necessary to pursue alternative livelihoods and improve the economic conditions of fishing communities to reduce pressure on fish stocks and promote sustainable fishing. Based on information from pangandaran lobster fishermen, the subsidies provided are small. Government subsidies aim to improve fishers' welfare by reducing fishers' operational costs, which can increase fishers' income and reduce poverty **(Husain _et al.,_ 2020; Notohamijoyo _et al.,_ 2020)**. While subsidies are critical to supporting fishers' livelihoods and economic well-being, they can also pose challenges related to resource sustainability and environmental impacts. Effective management and regulation of these subsidies is essential to ensure that they contribute positively to the economic and habitat goals of lobsters.

Social dimension

The results of the analysis show that the sustainability index of the social dimension of lobster is 48.27 in the less sustainable category. The ordination graph of the sustainability of the social dimension of lobster is shown in Fig. (8).
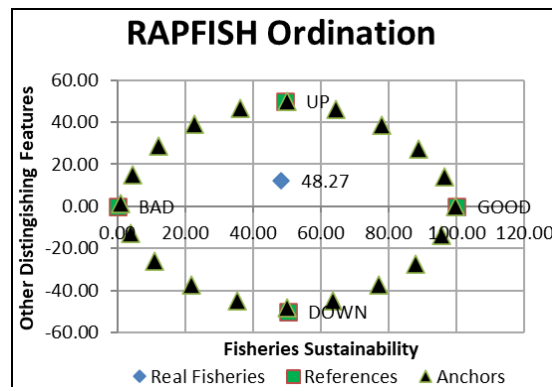

Fig. 8. Social dimension sustainability index

Based on the leverage analysis (Fig. 9), there are three attributes that are sensitive to the sustainability of the social dimension of lobster, namely the level of conflict, family participation in the utilization of SDI, and the level of education of fishermen. Based on information from fishermen, there has never been a conflict between lobster fishermen in Pangandaran district. Generally, conflicts among fishermen are caused by the competition for fishing areas **(Purnama _et al.,_ 2015)**, the use of different fishing technologies **(Daris _et al.,_ 2022)** and the scarcity of fish resources **(Nissa _et al.,_ 2024)**. Conflicts in lobster resource management can be avoided through joint management and stakeholder involvement. In addition, community norms are also an important element that can help reduce conflict and increase cooperation among fishers. The government

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should conduct effective communication with lobster fishers to understand the needs of fishers and ensure the implementation of regulations that can prevent conflicts between fishers.
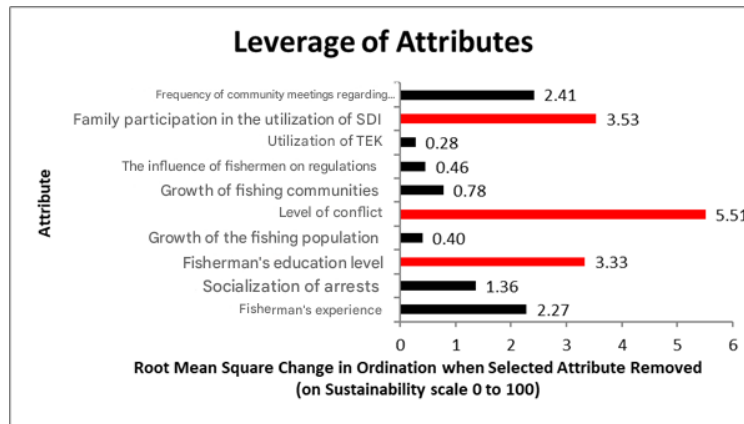

Fig. 9. Social dimension leverage analysis

Family participation in lobster resource utilization aims to improve the family economy. The participation is in the form of processing and selling the catch. This participation can be enhanced by forming a group of fisherwives to improve their competence in processing fishery products. In addition, the group can also be a forum for sharing experiences and information among fisherwives in processing fishery products. The level of education among fishermen has a significant impact on lobster fisheries management, which can affect the effectiveness of policy implementation and sustainable development of lobster resources. Based on field data, lobster fishers in Pangandaran district predominantly have never been to school and only a few are elementary school graduates.

The level of education will affect the insight and ability to understand management practices in lobster fisheries management. Fishermen who have higher education tend to be able to articulate and integrate their knowledge and experience with scientific judgment better, thus improving sustainable lobster fisheries management practices **(Stephenson *et al*., 2016)**.

Institutional dimension
The results of the analysis show that the sustainability index of the institutional dimension is 26.97 with the category of less sustainable. The ordination graph of the sustainability of the institutional dimension of lobster is in Fig. (10).
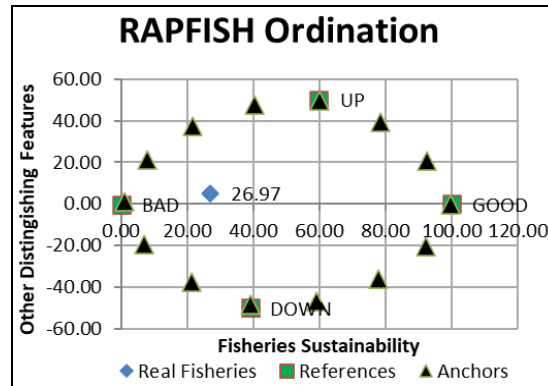
Fig. 10. Institutional dimension sustainability index

Based on the leverage analysis (Fig. 11), there are three attributes that are sensitive to the sustainability of the institutional dimension of lobster, namely the availability of law enforcement in the location, democracy in policy making and justice in law. Fishing activities in the State Fisheries Management Area of the Republic of Indonesia are supervised by the Ministry of Maritime Affairs and Fisheries through the Directorate General of Marine Resources and Fisheries Monitoring. The supervision is carried out by the Technical Implementation Unit for the Supervision of Marine and Fisheries Resources. Technical Implementation Unit of the Directorate General of Marine and Fisheries Resources Supervision in carrying out its duties is supported by the Marine and Fisheries Resources Monitoring Work Unit and the Marine and Fisheries Resources Monitoring Post which are spread throughout Indonesia. Based on information from fishermen, the availability of law enforcers at lobster fishing locations is still rare so that the practice of illegal lobster fishing is widely practiced.
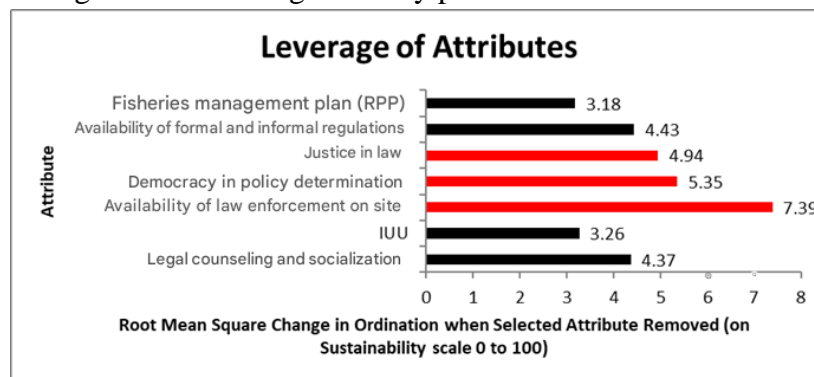

Fig. 11. Institutional dimension leverage analysis

Based on information in the field, fishermen feel that there is no democracy in determining current policies. One of the controversial regulations for fishermen is PERMEN KP No. 07 of 2024, one of which contains provisions related to lobsters caught must not be in egg-laying condition and the size of the group above 6cm for sand lobster, rock lobster, batik lobster and pakistan lobster and the size of the group above 8cm for other types of lobster. Fishermen feel disadvantaged by this regulation because if the

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lobster caught is below the size, they are required to release it back to its habitat. Economically, this can harm fishermen since fishermen use capital to catch lobsters. Fishermen hope that there is a solution regarding lobsters under the provisions that are accidentally caught can be exploited and not returned to their habitat.

In order to protect and empower small-scale fishermen, the government has made a series of laws and regulations as stipulated in law number 07 of 2016 concerning Protection and Empowerment of Fishermen, Fish Cultivators, and Salt Farmers. The law mandates the central government and local governments to facilitate and provide legal assistance to fishermen who experience legal problems in carrying out their business according to statutory regulations and experience fishing problems in other countries. based on information from fishermen, the absence of justice in the law is felt by fishermen, especially fishermen who are caught for violating KP candy regulations no 07 of 2024. This is supported by research **(Paka & Fitriono, 2024)** which states that the current criminal law policy in the EEZ region still has weaknesses in realizing social justice for local fishermen, so that law enforcement has not achieved social justice law enforcement.

Multi-dimensional

The results of the MDS rapfish analysis show that the sustainability index of the combined dimension of lobster is 53.91 with a fairly sustainable category. The rapfish ordination graph of the combined dimension of lobster is in Fig. (12).
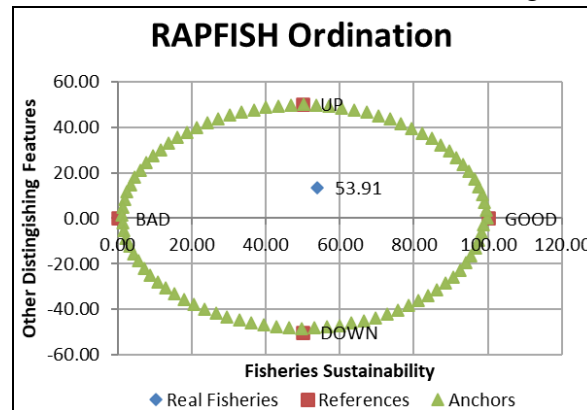

Fig. 12. Lobster multi-dimensional sustainability index

Each dimension shows a different sustainability index value. The ecological dimension is 63.28 with a fairly sustainable category, the technological dimension is 65.19 with a fairly sustainable category, the economic dimension is 67.85 with a fairly sustainable category, the social dimension is 48.27 with a less sustainable category and the institutional dimension is 26.97 with a less sustainable category. Comparison of the results of rapfish analysis on each dimension is visualized in the flyer diagram in Fig. (13).
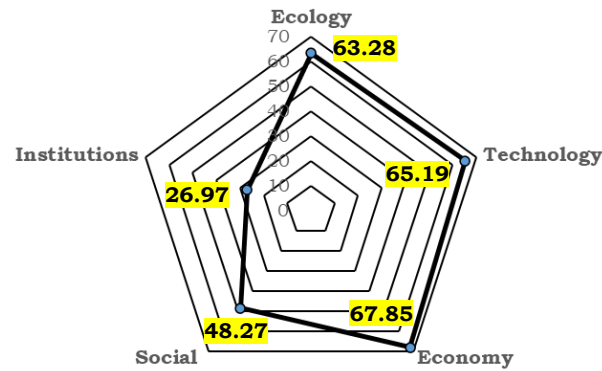
Fig. 13. Lobster sustainability index scatter diagram

Sustainability status of baby lobster (*Puerulus*)

Ecological dimension

The results of the analysis show that the ecological dimension sustainability index is 62.34 in the moderately sustainable category. The ordination graph of the ecological dimension sustainability index is shown in Fig. (14).
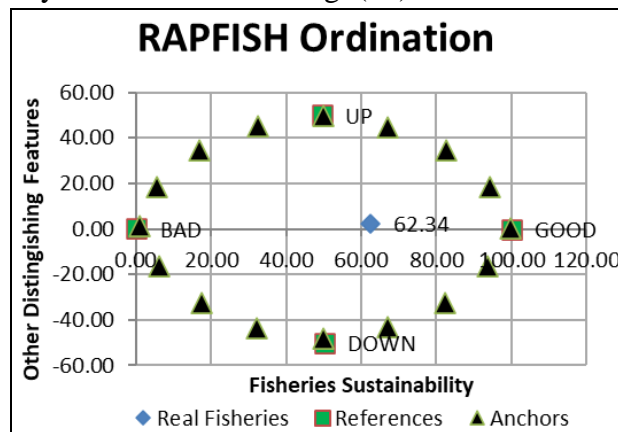

Fig. 14. Sustainability index of baby lobster in ecological dimension

Based on the results of the leverage analysis (Fig. 15), there are 3 attributes that stand out and show that these attributes are indicators that are sensitive to the value of the ecological dimension of the baby lobster sustainability index, namely the size of the catch before Lm, the size of the BBL, and the migration range. The catch of baby lobster falls into the category of catching lobster below length at first maturity (Lm). Overfishing of lobster fry can lead to a decline in lobster stocks, which in turn affects the long-term sustainability of lobster **(Froese *et al.,* 2016)**. The government has made regulations related to the quota for catching baby lobster, as stipulated in KP Regulation No. 28 of 2024 concerning Potential Estimates, Allowable Catches, and Quotas for Catching baby lobster (*Puerulus*). Cases of illegal capture of baby lobster often occur in the waters of the pangandaran district. The local government of Pangandaran district has made various

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efforts to reduce cases of illegal capture of baby lobster such as destroying fishing gear and releasing baby lobster that have been caught by fishermen.
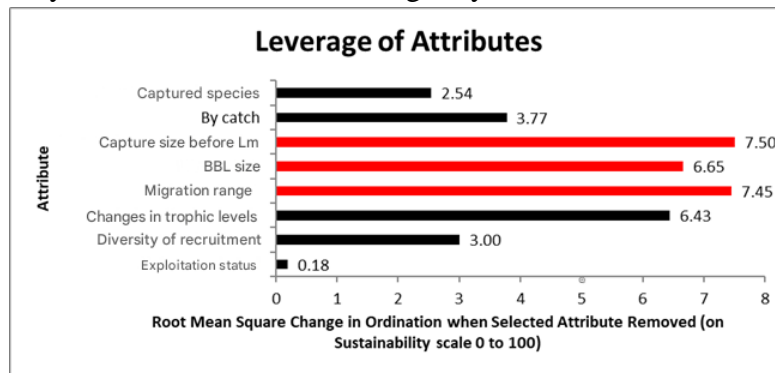

Fig. 15. Ecological dimension leverage analysis

Lobster migration is caused by climate change and habitat degradation that occurs due to loss of seagrass and seaweed which can disrupt ecological balance and increase food competition among marine species including lobsters **(Seitz *et al*., 2014; Sabino *et al*., 2021)**. Lobsters in Pangandaran Regency migrate 2-3 times a year. This happens because the Pangandaran coast is highly vulnerable to erosion **(Dhiauddin *et al*., 2019)** and human activities that cause water pollution **(Dewi *et al*., 2020)**. Lobsters also migrate due to reproductive activities. At the larval stage, lobsters are quite responsive in low light conditions so that they migrate vertically, namely swimming to the surface of the water and returning to the bottom of the water during the day **(McGeady *et al*., 2019)**. Puerulus begins the juvenile stadia and lives bentonically by feeding on small molluscs, worms, crustaceans and epiphytes such as coral algae.

Technology dimension
The results of the analysis show that the sustainability index of the lobster technology dimension is 73.31 with a fairly sustainable category. The ordination graph of the technology dimension sustainability index is in Fig. (16).
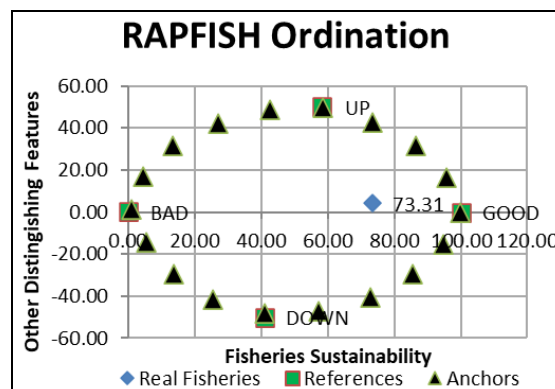

Fig. 16. Sustainability index of baby lobster in technology dimension

Based on the results of the leverage analysis (Fig. 17), there are 3 attributes that are sensitive to the sustainability of baby lobsters in the technology dimension, namely pre-sale processing, length of fishing time, and fishing aids. Pre-sale processing is the process carried out to keep baby lobsters alive. Based on information in the field, no processing is done to keep baby lobsters alive, so that in every fishing activity, there are always baby lobsters that have died and cannot be sold.
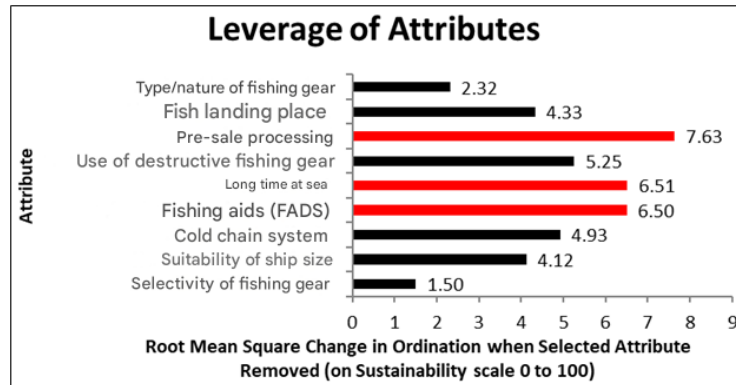

Fig. 17. Technology dimension leverage analysis

Fishermen in Pangandaran district catch baby lobsters with the duration of one day fishing. One day fishing has several good impacts such as the quality of baby lobster caught while still in fresh status thus increasing the price and profitability of the catch, reduced impact on the environment including reduced fuel consumption and lower emissions, reduced overfishing pressure (**Melnychuk** *et al.,* **2021; Sidiq** *et al.,* **2023; Cooke** *et al.,* **2024)**.

Fishermen in Pangandaran district use pocong nets to catch baby lobsters. Based on information in the field, fishermen do not use fishing aids commonly used in pocong nets, namely dip attractor lights. The light emitted by the dip attractor lamp emits light that functions as an attractant so that fish gather and remain concentrated around the light source (**Julianus & Patty, 2010)**. Dip attractor lights used as fishing aids can increase catches (**Hartono** *et al.,* **2019; Puspito** *et al.,* **2022)**. Operating the pocong net fishing gear without aids can maintain baby lobster stocks to avoid fishing pressure.

Economic dimension

The results of the analysis show that the sustainability index of the economic dimension of baby lobster is 49.79 with a less sustainable category. The ordination graph of the rapfish sustainability index is shown in Fig. (18).
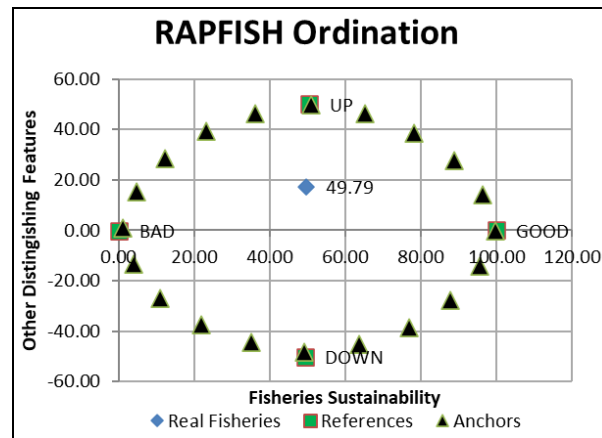
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Fig. 18. Sustainability index of baby lobster in economic dimension

Based on the results of the leverage analysis (Fig. 19), there are three attributes that are sensitive to the sustainability of baby lobsters in the economic dimension, namely government subsidies, main markets and average income. The main market for baby lobster is export to several countries such as Vietnam, Malaysia and Singapore. Fishermen catch baby lobsters and sell illegally to unlicensed traders rather than through official export flow schemes because countless other countries' traders offer higher prices. The high interest of fishermen to sell baby lobsters to the international market massively threatens the sustainability of lobsters in Indonesian waters.
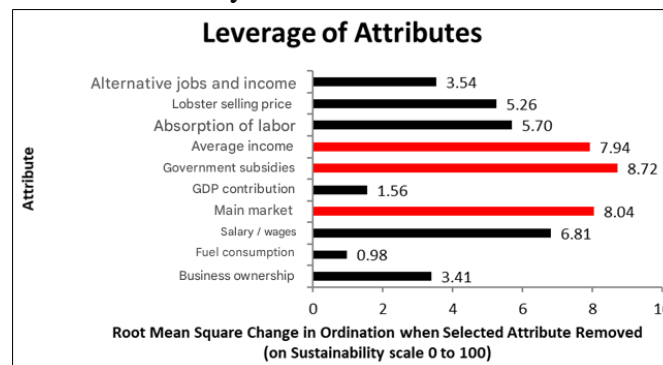

Fig. 19. Economic dimension leverage analysis

The average income of baby lobster fishers in Pangandaran Regency is above the minimum wage of Pangandaran Regency of IDR 2,221,724. Economic factors and poverty are significant contributors to overfishing **(Wijaya & Fauzie, 2020)**. It is therefore necessary to pursue alternative livelihoods and to improve the economic conditions of fishing communities to reduce pressure on fish stocks and promote sustainable fishing practices.

Based on information from pangandaran baby lobster fishermen, the subsidies provided are small. Government subsidies aim to improve fishers' welfare by reducing fishers' operational costs, which can increase fishers' income and reduce poverty **(Husain *et al*., 2020; Notohamijoyo *et al*., 2020)**. While subsidies are critical to supporting

fishers' livelihoods and economic well-being, they can also pose challenges related to resource sustainability and environmental impacts. Effective management and regulation of these subsidies is essential to ensure that they contribute positively to the economic and habitat goals of baby lobsters.

Social dimension

The results of the analysis show that the sustainability index of the social dimension of baby lobster is 28.94 in the less sustainable category. The ordination graph of the sustainability of the social dimension of baby lobster is depicted in Fig. (20).
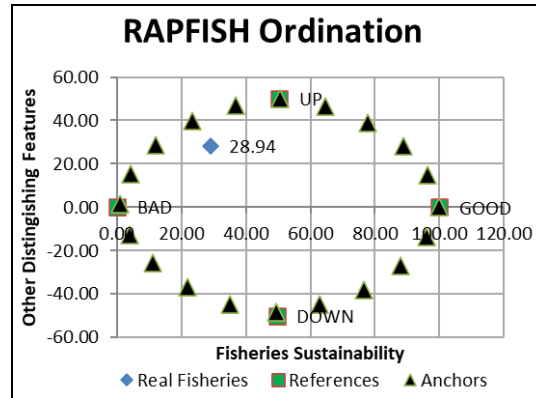

Fig. 20. Sustainability index of baby lobster in social dimension

Based on the leverage analysis (Fig. 21), there are three attributes that are sensitive to the sustainability of the social dimension of baby lobster, namely the level of conflict, socialization of fishing, and the level of education of fishermen. Socialization related to baby management is rarely carried out in Pangandaran district, socialization aims to increase fishermen's awareness and understanding of regulations and sustainable baby lobster catching practices. Socialization needs to be done regularly with regular frequency.

Based on information from fishermen, there has never been a conflict between baby lobster fishermen in Pangandaran district. Generally, conflicts among fishermen are caused by the competition for fishing areas **(Purnama** *et al.***, 2015)**, the use of different fishing technologies **(Daris** *et al.***, 2022)**, and scarcity of fish resources **(Nissa** *et al.***, 2024)**. Conflicts in the management of baby lobster resources can be avoided by means of joint management and stakeholder involvement. In addition, norms in the community are also an important element that can help reduce conflict and increase cooperation among fishers. The government should conduct effective communication with baby lobster fishers to understand the needs of fishers and ensure the implementation of regulations that can prevent conflicts between fishers.
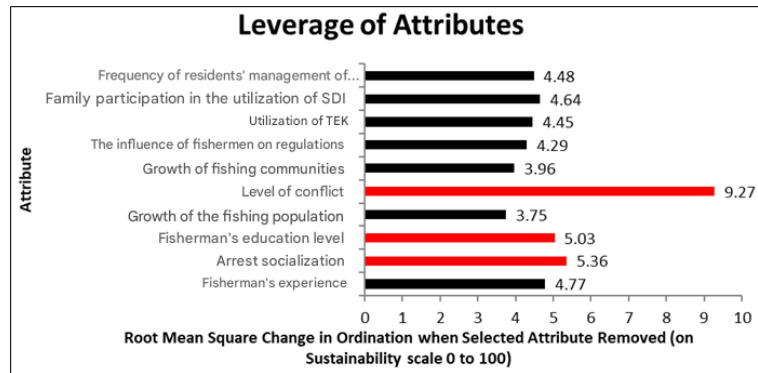
Fig. 21. Social dimension leverage analysis

The level of education among fishermen has a significant impact on baby lobster management which can affect the effectiveness of policy implementation and sustainable development of baby lobster resources. Based on field data, baby lobster fishermen in Pangandaran district predominantly have never been to school and only a few are elementary school graduates. The level of education will affect the insight and ability to understand management practices in baby lobster management. Fishermen who have higher education tend to be able to articulate and integrate their knowledge and experience with scientific judgment better, thus improving sustainable baby lobster management practices **(Stephenson *et al*., 2016)**.

Institutional dimension

The results of the analysis show that the sustainability index of the institutional dimension is 26.97 with the category of less sustainable. The ordination graph of the sustainability of the institutional dimension of baby lobster is illustrated in Fig. (22).

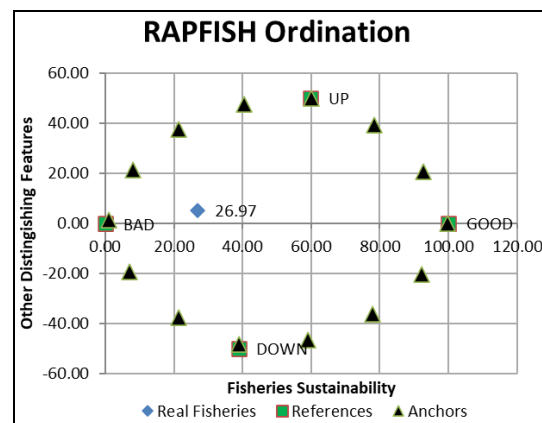**Fig. 22.** Sustainability index of baby lobster in institutional dimension

Based on the leverage analysis (Fig. 23), there are three attributes that are sensitive to the sustainability of the institutional dimension of baby lobster, namely the availability of law enforcement at the location, democracy in policy making and justice in law. Based on information from fishermen, the availability of law enforcement at the baby lobster

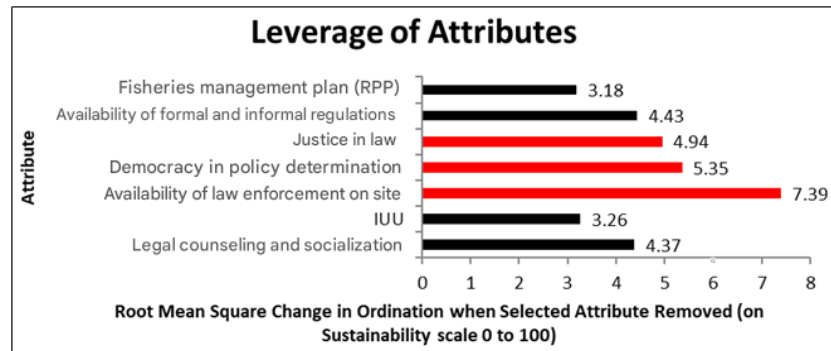fishing location is still rare so that the practice of catching baby lobsters illegally is widely practiced.

Fig. 23. Institutional dimension leverage analysis

Democracy in determining lobster management policies aims to make decisions based on the aspirations and needs of stakeholders, so that the regulations made are relevant to conditions in the field. Based on information in the field, fishermen feel that there is no democracy in determining the current policy. In order to protect and empower small-scale fishermen, the government has made a series of laws and regulations contained in Law No. 07/2016 on the Protection and Empowerment of Fishermen, Fish Cultivators, and Salt Farmers. The law mandates the central government and local governments to facilitate and provide legal assistance to fishermen who experience legal problems in running their business according to statutory regulations and experience fishing problems in other countries. based on information from fishermen, the absence of justice in the law is felt by fishermen, especially fishermen who are caught for violating KP candy regulations no 07 of 2024. This is supported by research **(Paka & Fitriono, 2024)** which states that the current criminal law policy in the exclusive economic zone (EEZ) region still has weaknesses in realizing social justice for local fishermen so that law enforcement has not achieved social justice law enforcement.

Multi-dimensional

The results of the rapfish MDS analysis show that the sustainability index of the combined dimensions of baby lobster is 47.57 in the less sustainable category. The rapfish ordination graph of the combined dimensions of baby lobster is shown in Fig. (24).
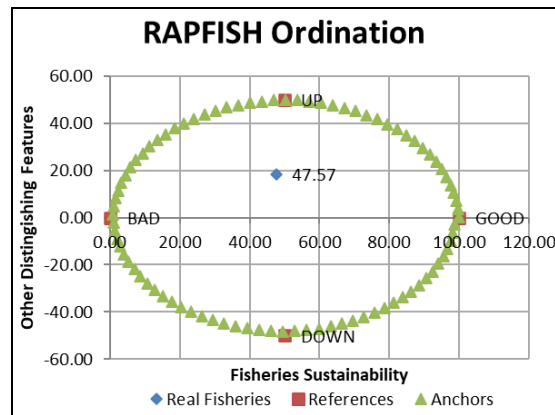
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Fig. 24. Multi-dimensional baby lobster sustainability index

Each dimension shows a different sustainability index value. The ecological dimension is 62.34 with a fairly sustainable category, the technological dimension is 73.31 with a fairly sustainable category, the economic dimension is 49.79 with a fairly sustainable category, the social dimension is 28.94 with a less sustainable category and the institutional dimension is 26.97 with a less sustainable category. Comparison of the results of rapfish analysis on each dimension is visualized in the flyer diagram in Fig. (25).
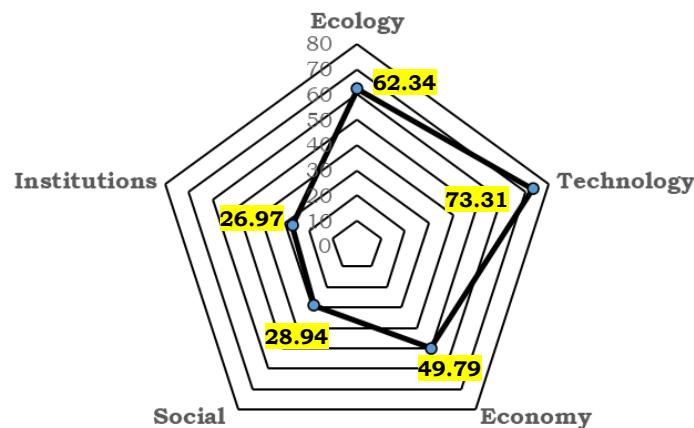
Fig. 26. Baby lobster sustainability index scatter diagram

Based on the diagram (Figs. 14, 26), it can be concluded that the institutional and social dimensions are the most influential dimensions in the sustainability of lobsters and baby lobsters. The social and institutional dimensions show the same sustainability category, namely unsustainable. This means that in the management of lobsters and baby lobsters in Pangandaran Regency, there are many problems and shortcomings in the social and institutional dimensions. The poor social conditions of the Pangandaran community, such as the lack of family participation in the utilization of lobster resources and the low level of education among fishermen, are the main causes of the low sustainability of lobster and baby lobster management in the social dimension. Institutionally, the lack of role of authorized institutions in planning, implementing, and

supervising lobster and baby lobster exploitation activities is the cause of low sustainability in the institutional dimension.

Statistical parameter analysis

The rapfish ordination value in each dimension can be the right estimator value if validation of the output is carried out. The validation shows the validity of the model that has been carried out and ensures that the results of rapfish analysis in each dimension have high validity **(Adiga *et al*., 2015)**. Validation of rapfish analysis results in each dimension uses 3 outputs, namely the coefficient of determination (R^2 values), stress values, and Monte Carlo analysis values. The results of rapfish analysis validation are deposited in Table (3).

Table 2. Validation of lobster statistical parameters

No	Validation	a	b	c	D	e	f
1	Coefficient of determination (R^2 values)	94.56	94.71	95.04	94.89	94.64	95.74
2	Stress values	14.14	13.48	13.33	13.73	14.18	12.76
3	Monte carlo value	62.29	64.60	67.59	50.09	26.29	53.00
4	Rapfish ordination value	63.28	65.19	67.85	48.27	26.97	53.91

Description: a = ecological dimension, b = technological dimension, c = economic dimension, d = social dimension, e = institutional dimension, f = multi-dimensional.

Table 3. Validation of baby lobster statistical parameters

No	Validation	a	b	c	D	e	f
1	Coefficient of determination (R^2 values)	94.23	93.46	94.26	95.00	94.64	95.68
2	Stress values	13.90	13.87	13.44	13.38	14.18	12.74
3	Monte carlo value	59.99	69.95	50.98	30.62	29.22	48.40
4	Rapfish ordination value	62.34	73.31	49.79	28.94	26.97	47.57

Description: a = ecological dimension, b = technological dimension, c = economic dimension, d = social dimension, e = institutional dimension, f = multi-dimensional.

According to **Kavanagh (2001)**, a coefficient of determination value above 80% indicates that the sustainability index estimation model is good and can be used. A good coefficient of determination value is close to 1 or 100%, which means that the input data are perfect and can be trusted to represent the actual conditions. Based on the analysis results, it was found that the coefficient of determination (**R²** values) for each dimension was above 80% and close to 1. These values indicate that the model used can be well explained.

A good stress value is close to 0, and the tolerable stress value limit is less than 25% **(Kavanagh, 2001)**. The results of the analysis in each dimension show a stress

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value of less than 25%, which means that the model and analysis are feasible for use. The difference between the Monte Carlo analysis results and the rapfish ordination values in each dimension shows the confidence interval of the rapfish analysis results. A difference of less than 5% indicates that the accuracy of the model and analysis is very high or precise. Therefore, it is concluded that the rapfish model developed to assess the sustainability index in each dimension is reliable and accurate.

CONCLUSION

The multidimensional sustainability index for lobsters is 53.91, categorized as moderately sustainable, while the multidimensional sustainability index for baby lobsters is 47.57, categorized as less sustainable. The institutional and social dimensions are the most influential dimensions in the sustainability of lobsters and baby lobsters. The social and institutional dimensions show the same sustainability category, namely less sustainable. This means that in the management of lobsters and baby lobsters in Pangandaran District, there are many problems and shortcomings in the social and institutional dimensions. The practice of exploiting baby lobsters must be given special attention, starting from stock calculations, allowable catch amounts, habitat conditions, and supervision of fishing practices.

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