

Efficiency Level Analysis of Mini Purse Seine Fisheries Business Based on Small Pelagics in Moti District, Ternate City

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Abstract

North Maluku is an archipelagic province with great potential for small pelagic fisheries resources, especially in Moti Island which is included in Fisheries Management Area (WPP) 715. However, the utilisation of these resources has not been optimal and the Mini Purse Seine fishery business activities still face various obstacles such as limited facilities, high fuel prices, and low fish selling prices. This study aims to analyse the technical factors of production that affect catches, assess the level of efficiency of Mini Purse Seine fisheries, and provide recommendations for business improvement in Moti District, Ternate City. Data were collected through surveys, interviews, and literature studies, with Principal Component Regression and Data Envelopment Analysis (DEA) approaches using SPSS 26 and SBFA 4.0 software. The results showed that vessel size, duration of fishing, fuel, engine capacity, length of fishing gear, number of crew members, and number of trips affected the catch by 82.6%. There are 3 technically efficient business units, 4 near efficient units, and 2 inefficient units. Recommendations for improvement include reducing operational and investment costs, increasing production and profits, and reducing the number of crew members for certain units. This research provides a basis for more efficient and sustainable management policies in support of improving the welfare of fishermen on Moti Island.

Keywords: Data Envelopment Analysis, Efficiency, Mini Purse Seine, Small Pelagic, Regression.

1. Introduction

North Maluku is an archipelago province which has 79% sea area and 21% land area and has 4 Fisheries Management Areas (WPP), including WPP 714, 715, 716, 717 (DKP, 2021). Small pelagic fisheries from 4 WPPs in North Maluku have a potential resource (standing stock) of 1,373,349 tonnes, but until now the level of utilisation has not been maximised and has only reached 21.4%, there is still unmanaged potential of 79.6%. This indicates that the potential utilisation of small pelagic fishery resources in North Maluku is still relatively low (under exploited) and still has opportunities to develop businesses and fishing activities.

Moti Island is part of the WPP 715 zone where the potential resources (standing stock) of fisheries, especially small pelagics in this WPP zone, reached 443,944 tonnes with a total allowable catch (JTB) of 310,761 tonnes. The current managed potential has reached 70% and the remaining 30% has not been managed. This informs that there is still room to conduct small pelagic fishing business activities in WPP 715. Potential small pelagic fish resources that are still the main commodity on Moti Island are julung (*Hemiramphidae*), swallowfish (*Decapterus macarellus*) and selar/tude (*Atule mate*) which are caught with various fishing gear, one of which is Mini Purse Seine (Amin & Kasim, 2015).

Activities carried out by fishermen in Mini Purse Seine operations on Moti Island include preparation of boats, boat engines, fishing gear, additional equipment and supplies, and supplies. The



five preparations are very necessary in fishing using Mini Purse Seine fishing gear. The activities of fishermen and Mini Purse Seine fisheries business actors in Moti District are still operating. However, they are faced with several problems.

Based on the Capture Fisheries Study Report, it states that some of the main problems faced by fishermen in the minapolitan area of Ternate City, including on Moti Island, include limited facilities, high fuel prices, and low fish selling prices. This condition has been a challenge faced by business actors and fishermen on Moti Island for years. Therefore, if there is no effort to strengthen the technical management of production and operational cost management, it will certainly have a negative impact on the efficiency of small pelagic fisheries business units on Moti Island.

Salim et al. (2024), explained that progress in a fisheries business is influenced by good management and management. Therefore, one way to overcome the problems faced by fishermen and fisheries business actors on Moti Island today is to carry out good management and management, namely the use of resources that must be efficient. In other words, optimising the use of input resources (investment, and total costs) used to obtain optimal output resources (catch and profit) in order to support the sustainability of fishing businesses and the welfare of fishermen on Moti Island.

There are several benefits of fisheries efficiency, namely maximising catches with minimal effort. Conservation of natural resources and maintaining the sustainability of fish populations and reducing operational costs in fisheries. Reducing negative impacts on the environment and increasing the sustainability of fish resources (Moniharapon et al., 2024).

Based on this description, the author is encouraged to explore the study of 'Analysis of the Efficiency Level of Small Pelagic-Based Mini Purse Seine Fishery Business Units in Moti District, Ternate City' the results of this study are expected to be useful for business unit actors and fishermen in terms of increasing the level of efficiency.

The potential of small pelagic fisheries resources on Moti Island is currently still the main commodity, however, small pelagic fisheries businesses in Moti District are still faced with several problems that hinder the productivity of business units to grow. The background previously described shows that the marketing system in the research location can be detrimental to fishermen and business actors. This is because the unavailability of Fish Auction Sites (TPI) and the high price of fuel oil (BBM) are not directly proportional to the selling price of fishermen's catch.

The marketing system of small pelagic fish is also almost forced to sell directly to consumers at low prices. Therefore, the profit obtained is relatively small. This problem is exacerbated if there is no effort to fix the use of efficient production factors, it will certainly have a negative impact on the efficiency of small pelagic fisheries business units on Moti Island. Based on this, the problems in this study can be formulated as follows:

1. What factors influence the catch of Mini Purse Seine fishermen in Moti District, Ternate City?
2. What is the efficiency level of mini purse seine fisheries in Moti District, Ternate City?
3. What are the recommendations for improvement for mini purse seine fisheries business units in Moti District, Ternate City?

The purpose of this research is to answer the problems that have been formulated previously. This study aims to determine the technical factors of production that affect the catch of small pelagic-based Mini Purse Seine fishermen on Moti Island. In addition, this study also aims to analyse the level of efficiency of Mini Purse Seine fisheries in the region. Furthermore, this research is expected to describe relevant and applicable policy recommendations to improve the performance of Mini Purse Seine fisheries in Moti District.

2. Literature Review

2.1. Fisheries Business

Fisheries is one of the fields of study that investigates policies related to the management and conservation of fishery resources, aquatic organisms, and fishery resources. The fisheries enterprise system includes all activities related to the management and utilisation of fish resources and their environment, from pre-production to production, processing, and marketing (Yusfiani et al., 2019). Fisheries enterprise is a financial movement, where people develop their normal fisheries assets in a reasonable way to get the maximum profit with human assistance from the government. Fisheries business refers to economic activities related to the capture, cultivation, processing, marketing, and trade of fish and fishery products involving various aspects including waters, fish resources, technology, management, and markets.

2.2. Fisheries Business Management

Fisheries business management can be defined as a series of planning, organising, directing and supervising processes in a business or business system that uses fisheries resources to achieve maximum profit (Salim et al., 2024). Fisheries business management includes planning, organising implementing, and supervising activities related to the capture, cultivation, processing, and marketing of fishery products. The goal is to optimise production and profit while maintaining the sustainability of fisheries resources (Fauzi, 2010).

2.3. Small Pelagic Fisheries

Small pelagic fish is a group of fish that live quite actively in surface waters of the sea. Several types of pelagic fish consisting of large pelagic fish that occupy oceanic waters (high seas). Small pelagic fish that live in coastal waters (neritic zone) with a depth of approximately 200 m (Dahuri, 2003). Small pelagic fish resources have a role in the economic development of the region, especially waters that have the potential of small pelagic fish resources. The main role of small pelagic fish resources is the fulfilment of nutrition and protein for people in a region. In addition, economically, it can increase the income and welfare of the community, especially fishermen in coastal areas, as well as support fish processing activities (Nelwan et al., 2015).

2.4. Small Pelagic Resource Management

Management is the skill and study of organising, coordinating, planning, and controlling assets to achieve stated goals. These administrative components have a very important role in the progress of the life pattern of a business or organisation (Oliveira et al., 2015). Pelagic fish resources are a very abundant fish asset in Indonesian waters with an estimated 75% of total fish stocks or 4.8 million tonnes/year (Zainuddin, 2021). Small pelagic fish would be a financially significant fish asset biologically and an important part of different marine environments. This asset is a neritic asset because its transport area is predominantly around the coast (neritic population).

2.5. Efficiency

Efficiency is a reflection of the ability of a system or organisation to produce desired results using a minimum amount of resources. In the context of business, efficiency means achieving goals at minimal cost (Afandi et al., 2017). Efficiency is achieved when people cannot obtain more of one good without reducing the amount of other goods produced. In other words, efficiency is achieved when society is at the point of production that is on the production possibility line. Efficiency can be defined as a measure of the extent to which the resources used to produce a product or service have been put to the best use, without waste or overuse. In small pelagic fisheries, efficiency also considers ecological

and social perspectives. Ecological productivity reflects the extent to which fishing effort successfully limits adverse impacts on the marine environment and fish assets, while social effectiveness reflects how fishing effort provides monetary benefits and government assistance to coastal networks (Hasid et al., 2022).

2.6. Factors Affecting the Efficiency of Pelagic Fisheries Businesses

Factors affecting the efficiency of small pelagic fishing can vary depending on the location, infrastructure, technology and policies in place. Some important factors that can affect the efficiency of small pelagic fishing include:

1. Use of Technology: Utilisation of modern fishing gear and navigation technology that is appropriate to local conditions.
2. Scale of the enterprise: The number of vessels and fishers involved, and the level of business organisation.
3. Access to Markets and Infrastructure: Availability of ports, auction sites, processing facilities, and transport.
4. Fishermen's Skills and Knowledge: Fishermen's level of training and understanding of fishing techniques and resource management.
5. Fisheries Resource Management: Policies and regulations that support sustainability and control resource exploitation.

2.7. The Role of Small Pelagic Fisheries in the Local Economy

Small pelagic fisheries play an important role in the local economy, both as the main source of income for fishers and their families and as a driver of other economic sectors such as fish processing, distribution and trade. Catches such as anchovies, lemur and flying fish not only provide income for coastal communities, but also strengthen food security by providing an affordable source of animal protein. In addition, the sector drives local economic growth through job creation and its contribution to regional development, making it one of the key foundations in the economic development of coastal areas.

3. Methods

3.1. Research Time and Location

This research was conducted during December to April 2024, the location of this research was carried out in Moti District, Ternate City, North Maluku Province. The following is a map of the research location.

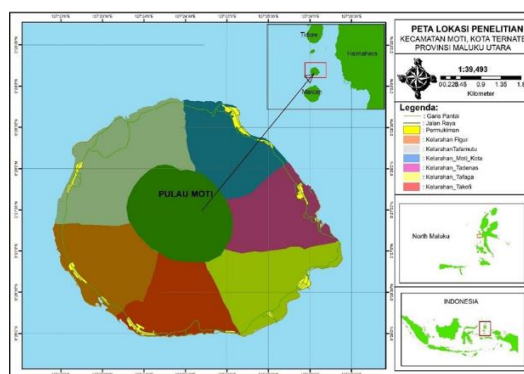


Figure 1. Map of the research location

Source: Primary Data, 2024

3.2. Research Methods

3.2.1. Data Collection Method

The data collection method used in this research is descriptive method, namely by conducting direct surveys to the field and interviews. Data collection in this study is primary data collection and secondary data.

a. Primary Data

Primary data required are data on production factors (gear size, vessel size, business capital, number of trips, fuel, operational costs, engine capacity, investment costs, number of crew members), and catches in small pelagic mini purse seine fisheries.

b. Secondary Data

Secondary data is data obtained indirectly through literature studies of library materials and existing data. Secondary data obtained in the study are from the official website of the Central Statistics Agency (BPS), the North Maluku Marine and Fisheries Service (DKP) and by reading literature such as literature books, journals related to the subject of research.

3.2.2. Sampling Method

The sampling technique used in this study is the total population of mini purse seine business units in the research location with a total of 9 (nine) business units. This is based on Arikunto (2010), which states that if the total population is <100 then the sample must be taken as a whole.

3.3. Data Analysis Method

The data analysis used in this study to identify and determine the technical factors of production that affect the catch of Mini Purse Seine fishermen is the Principal Component Regression (PCR) model, with the help of the Social Package of Statistics Software (SPSS 26) programme. The analysis of the efficiency level of the Mini Purse Seine business unit in Moti District was carried out by implementing the Data Envelopment Analysis (DEA) model, which was operationalised through the Banxia Frontier Analyst Software (SBFA 4.0). The following are the stages of analysis applied in this study.

3.3.1. Principal Component Regression (PCR)

Principal Component Regression (PCR) is a statistical method that consists of two main stages, namely performing Principal Component Analysis (PCA) to transform the original variable into a number of uncorrelated principal components, followed by regression on the dependent variable using these components. The PCR model can be expressed as a linear regression equation with the principal components as predictors and the dependent variable as the final outcome. The principal component regression (PCR) model can be written with the equation as follows:

$$Y = w_0 + w_1PC_1 + w_2PC_2 + \dots + w_mPC_m$$

Principal components are linear combinations of standardised variables and are determined through the coefficient score matrix. The stages of PCR analysis include the calculation of the component score coefficient matrix, regression on the dependent variable, and statistical analysis with the t test (partial), F test (simultaneous), and coefficient of determination (R^2). The F test is used to see the joint effect of independent variables on the dependent variable, while the t test is used to test the effect of each independent variable individually. The greater the R^2 value (close to 1), the stronger the

model explains the relationship between the independent variable and the dependent variable; conversely, a low R^2 value indicates a weak relationship.

3.3.2. Data Envelopment Analysis (DEA)

The efficiency analysis in this study uses non-parametric Data Envelopment Analysis (DEA) method with Variable Returns to Scale (VRS) approach. The purpose of this model is to assess the relative efficiency of each business unit or Decision-Making Unit (DMU) in producing the same or greater output with the same or smaller input than other units (Lam, 2015). This study analyses 9 DMUs in Moti sub-district, with efficiency measured by the ratio of total output to total input, where the best DMU scores 100 and the others score a relative score between 0 and 100.

DEA can be conducted with either an input or output orientation, and in this study an output orientation was used. Based on Fauzi (2010), the DEA formulation includes an objective function to maximise the level of efficiency (θ), with linear constraints linking the output and input weights of each DMU. Inputs consist of crew size, investment, and operating costs, while outputs include total production and profit. Efficiency is calculated based on how optimally inputs are utilised to produce outputs, with the intensity variable (z_i) as the weight for each DMU.

4. Results and Discussion

4.1. Description of Population Demographics

The population of Kecamatan Moti is approximately 4,677 people. The sub-district consists of six villages, namely Moti Kota, Tafamutu, Figur, Takofi, Tafaga and Tadenas. Moti Kota is the kelurahan with the largest number of households, with 374 households accounting for 28.21 per cent of the total population. Tafamutu has 251 families (18.93%), Figur 174 families (13.50%), Takofi and Tafaga 197 families each (14.86%), and Tadenas 128 families (9.65%). Thus, Moti Kota has the highest population concentration, while Tadenas has the lowest. Until 2023, the number of fishermen in Moti Sub-district who are still active and recorded in the population data of Ternate City is around 173 people. These fishermen are spread across six kelurahan, as shown in the following table.

Table 1. Number of fishermen in Moti sub-district

Village	Fisherman	Percentage (%)
Moti City	82	47,4 ⁰ %
Tafamutu	28	16,2 ⁰ %
Figure	19	11,0 ⁰ %
Takofi	13	7,5 ⁰ %
Tafaga	22	12,7 ⁰ %
Tadenas	9	5,2 ⁰ %
TOTAL	173	100,0 ⁰ %

Source: Dukcapil (2023)

It can be seen that in Moti Sub-district, Ternate City, Moti Kota Village has the highest percentage of fishers at 47.4%. In contrast, Tadenas Village has the lowest number of fishermen with a percentage of 5.2% of all fishermen in Moti Sub-district.

4.2. Characteristics of Respondents

This study focuses on the characteristics of respondents, which mainly consist of vessel owners, fishing gear owners, and skippers.

4.2.1. Age

Age greatly affects the maturity of a person to think in making a decision, therefore in this study, the age of respondents as ship owners and ship captains has an age range of 35 to 69 years.

Table 2. Characteristics of Respondents Based on Age

No	Age	Total	Percentage %
1	35 – 41	2	13
2	42 – 48	3	20
3	49 – 55	7	47
4	56 – 62	2	13
5	63 – 69	1	7
Total		15	100

Source: Primary data (2024)

Based on table 2, it can be seen that ship owners and skippers as business managers with the most age range are 49 to 55 years as much as 47%. In general, ship owners and skippers with Mini Purse seine fishing gear are included in the productive age of 35 to 69 years.

4.2.2. Education

Table 3. Characteristics of Respondents Based on Education

No	Education	Total	Percentage %
1	Primary School	4	27
2	Junior High School	4	27
3	Senior High School	7	46
Total		15	100

Source: Primary Data (2024)

Of all respondents, the majority had an education up to senior high school level, at 46 per cent. Interviews found that none of the boat owners or skippers had formal education at the Bachelor's degree level or higher. With this level of education, the explanation stating that experience or expertise in managing fisheries businesses is mostly obtained from practical experience rather than formal education is relevant and acceptable (Sukiyono & Romdhon, 2016).

4.3. Mini Purse Seine Capture Fishery

Capture fisheries business utilising Mini Purse Seine gear with the main target of small pelagic fish (sorihi) in Moti District, Ternate City, has been operating for approximately 16 years until now. The results of observations at the research site found that the number of Mini Purse Seine fishing fleets that are still actively operating is 9 units, with various specifications.

4.3.1. Catch Season and Production

Small pelagic fishing on Mini Purse Seine gear on Moti Island, is faced with 3 seasons namely, peak season, famine, and ordinary. Based on the results of interviews, the peak season occurs in April -

June, the normal season occurs in July - November while the lean season occurs in December - March. The following table shows the production and fishing season of small pelagic fish in Moti sub-district.

Table 4. Production and Catch Season Data

Season	Total Production (Kg)	Price (Rp/kg)	Length of time	Number of Trips	Production Value (Rp)
Peak	134,100	15,000	3 Months	32	2,011,500,000
Medium	88,550	15,000	5 Months	35	1,328,250,000
Famine	8,840	20,000	4 Months	10	176,800,000
Total	231,490		12 Months	77	3,516,550,000

Source: Primary Data (2023)

Table 4 shows that the highest average volume per trip was recorded in the regular season with an average of 35 trips/season followed by the peak season of 32 trips/season and the lean season of 10 trips/season. In the lean season, fishermen are faced with strong winds and large waves so that in this season most fishermen prefer not to go to sea or reduce fishing trips. The table indicates that the catch volume fluctuates throughout the year, with the highest gain in the peak season and the lowest point in the lean season. The fluctuations in catch volume, production value, and number of trips throughout the year show how seasonality strongly influences the performance of the Mini Purse Seine fishery on Moti Island. This pattern reflects fishers' dependence on natural cycles, where the success of their business is strongly influenced by environmental changes.

4.4. Catchment Area of Mini Purse Seine Fishermen in Moti District

The fishing grounds of small pelagic fish Mini Purse Seine fishermen are within Fisheries Management Area (WPP) 715, especially in the Southern Waters of Halmahera and its surroundings. Based on the coordinates of the fishermen obtained at the research location, the distance from the Fishing Base to the Fishing Ground ranges from 70 - 145 miles. The following is a map of the Moti fishermen's catchment area.

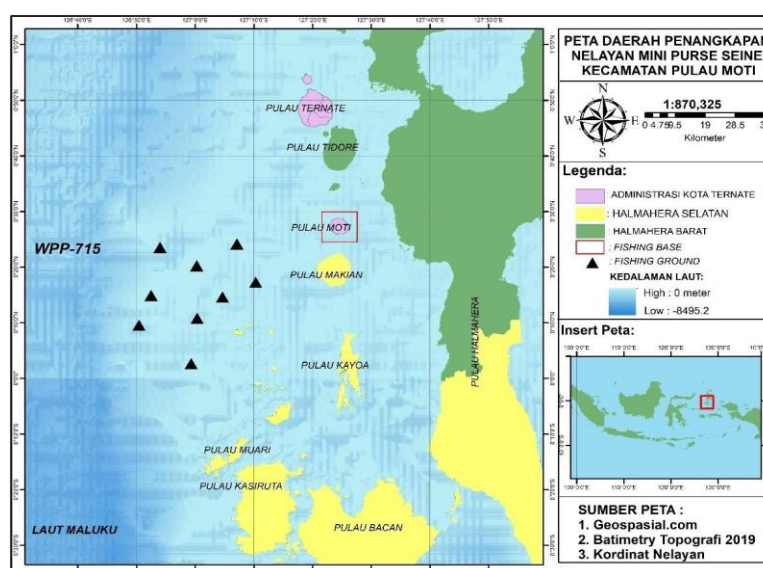


Figure 2. Catchment Area Map of Moti Fishermen

Source: Processed Data (2024)

4.5. Data Processing Results

In this study, the technical factors used to predict the catch of Mini Purse Seine (Y) are Ship Size (X_1), Duration at Sea (X_2), Fuel (X_3), Engine Capacity (X_4), Length of Fishing Gear (X_5), Number of Crew (X_6), and Number of Days at Sea (X_7). To measure the influence of technical production factors on the catch of Mini Purse Seine, a combination of Principal Component Analysis (PCA) and multiple linear regression called Principal Component Regression (PCR) was analysed.

4.5.1. Principal Component Analysis (PCA) Calculation Results

The first stage in the PCR (Principal Component Regression) method is to perform PCA (Principal Component Analysis) analysis to reduce the dimensions of the data without losing the information contained therein. Principal Component Analysis (PCA) starts with the Bartlett test, Kaiser Meyer Olkin (KMO). The following are the stages of PCA analysis test results.

a. KMO and Bartlett test

The hypotheses formed in this test are as follows:

H_0 = there is no correlation between independent variables

H_1 = there is a correlation between independent variables

Based on the test results, the test results are as follows:

Table 5. KMO and Bartlett's Test Results

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0,696
Bartlett's Test of Sphericity	Approx. Chi-Square	50,883
	df	21
	Sig.	0,000

Source: Processed Data (2024)

In table 5, shows that there is a sig value. $0.00 < 0.05$ so it can be concluded that there is a correlation between the independent variables on the data of technical factors of production of Mini Purse Seine fishing business. Then in the KMO test results there is a value of 0.696 which means that the sampling adequacy can meet the requirements of PCA analysis because the value obtained is greater than 0.5. Furthermore, to determine the number of components formed can be seen from the component factors generated through the PCA scree plot graph as in the following figure.

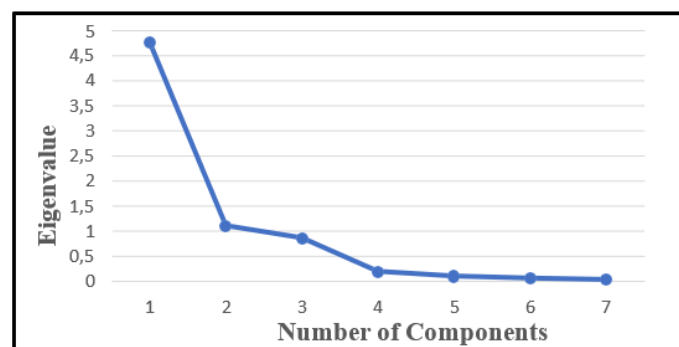


Figure 3. Scree Plot Graph

Based on Figure 3, it is found that there are only 2 main component factors that have an eigenvalue > 1. So, it can be concluded that only 2 components are formed. Wangge (2021) explained that components with an eigenvalue of more than 1 can be retained and made the main component formed. Then to see the technical production factor variables belonging to the PC1 component and the PC2 component, it can be seen in the Varimax rotation results in the PCA method as follows.

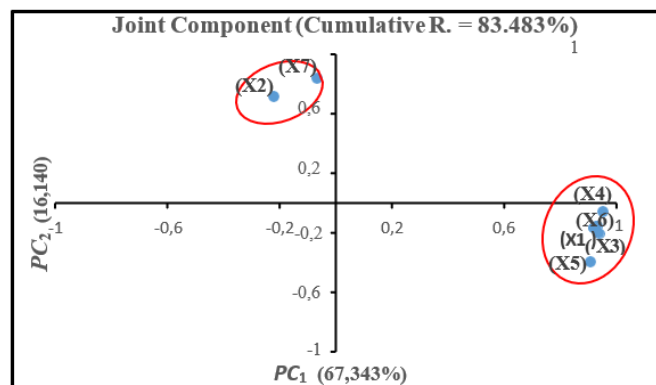


Figure 4. Varimax Rotation Graph of PCA Results

The results of PCA analysis that has successfully reduced the 7 independent variables into 2 main components (PC1 and PC2) with a total cumulative variance of 83.483% so it can be concluded that these two components have been able to explain the variance in the data of technical factors of production of Mini Purse Seine fisheries. Abdi and Williams (2010), explained that, if the main component can explain the total variance above 70% then the number of components is considered representative enough and able to explain the variance in the data. The results of the PCA analysis show that the PC1 component, which explains 67.343% of the variability, is dominated by the variable size of the vessel (X1), the amount of fuel (X3), engine capacity (X4), the length of the fishing gear (X5) and the number of crew members (X6) where this component represents the physical and operational capacity of fishing gear in Mini Purse Seine fisheries.

Meanwhile, the PC2 component, which explains 16.140% of the variability, is dominated by the variables of fishing duration (X2) and number of trips caught (X7), which reflect the time factor and intensity of fishing activity. The position of the variables close together indicates a high correlation, while those far apart indicate a weaker relationship. The results of this analysis also inform us that most of the variability in the technical factors of production data can be explained by the dimensions of operational capacity and fishing activity, thus simplifying interpretation without losing important information.

4.5.2. Multiple Regression Test of Principal Components on Catch Rate

The component factors that have been obtained through the Principal Component Analysis (PCA) method will be further analysed using the multiple regression method to obtain a regression model. The following are the results of multiple regression tests, namely regression with the main components formed through PCA.

a. Test Coefficient of Determination (R^2)

The results of the coefficient of determination (R^2) test on the main components formed can be seen from the coefficient of determination value in the following table:

Table 6. Test Results of the Coefficient of Determination

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.910 ^a	0,829	0,772	2,279472

Predictors: (Constant), Komponen PC_1 , PC_2 ,

Table 6 shows that 82.6% of the variability of the dependent variable can be explained by the two main components formed (PC_1) in this model. While the remaining 17.4% is explained by other factors outside this model.

b. Simultaneous Test (F)

The simultaneous F test is used to see the joint effect of the main components formed (PC_1) on the catch variable (Y).

Table 7. Simultaneous Test Results (F)

ANOVAa						
	Model	Sum of Squares	df	M Square	F	Sig.
1	Regression	151,126	1	75,563	14,543	0,005b
	Residual	31,176	6	5,196		
	Total	182,302	8			

Table 7 shows the F-count value of $14.543 > 5.32$ with a significance value of $0.00 < 0.05$. With this result, H_0 is rejected and H_1 is accepted. This means that all variables contained in the PC_2 and PC_1 components jointly affect the catch of Mini Purse Seine fishers (Y).

c. Partial Test (t)

The t-test is used to determine the significance of the effect of each main component (PC_1) and (PC_2) on catch (Y).

Table 8. Partial Testing (t test)

	Coefficient		t-Statistic	sig.	Description
	Constant	25,703	33,828	0,000	There is an Influence
Ship Size					
FUEL					
PC1	Engine capacity	4,094	5,080	0,002	There is an Influence
	Length of fishing gear				
CREW					
PC2	Duration at sea	-1,459	-1,811	0,120	No effect
	Number of trips				

Dependent Variable: Y (Catch)

Based on table 8, it can be explained that the t test of the main component with the dependent variable Y (catch) is: The t test of the main component (PC_1) with the catch (Y) shows the value of $t > t$ table which is $5.080 > 2.367$ and a significant value of $0.002 < 0.05$. This means that the hypothesis H_0 is rejected and H_1 is accepted. This means that the hypothesis H_0 is rejected and H_1 is accepted, so it can

be concluded that partially the catch on the Mini Purse Seine fishing gear has a real and significant effect by the PC_1 component or in other words the variable size of the ship (X_1), fuel oil (X_3), engine capacity (X_4), length of fishing gear (X_5) and crew (X_6) contained in the first component (PC_1) is a factor that can affect the catch of Mini Purse Seine in Moti District.

The t test of the main component (PC_2) with the catch (Y) shows the calculated t value < t table, namely $-1.811 < 2.367$ and a significant value of $0.120 > 0.05$. This means that the hypothesis H_0 is accepted and H_1 is rejected, so it can be concluded that statistically the catch on the Mini Purse Seine fishing gear has no significant effect by the PC_2 component or in other words, the variables of fishing duration (X_2), and the number of fishing trips (X_7), contained in the main component of PC_2 statistically have no effect on the catch of fishermen so that the variables of fishing duration (X_2) and (X_7) number of trips, are not included in further analysis.

The reason for the lack of effect of these two variables is because the use of FAD-based fishing operation systems is one of the reasons why the variables of duration of fishing and number of trips do not have a significant effect on the catch of mini purse seine fishers in Moti District. FADs located in the research location allow fishermen to easily determine the fishing location without requiring a long time to search for the presence of fish. Moniharapon et al. (2024), explained that the presence of FADs is very useful in cutting working hours because pelagic fish tend to concentrate in the area around FADs. Thus, the duration of fishing is no longer the main factor in the success of the catch.

The interview results also revealed that the frequency of fishing trips made by Moti fishers is strongly influenced by the FAD guard's information on the presence of small pelagic fish. If there are no pelagic fish entering the FAD area, then increasing the number of trips will not increase the catch, so this variable is not significant. This indicates that the success of fishermen in Moti sub-district in catching fish depends more on the presence of fish around FADs and the effectiveness of gear management such as gear length, engine power, number of crew rather than the intensity or duration of fishing effort.

4.6. Estimation of the Effect of Technical Production Factors on the Catch of Mini Purse Seine Fishermen in Moti District

The results of the main component regression model will then be multiplied by the previous score component matrix to obtain a regression equation (Çamdevýren et al., 2005). The following are the results of the PCR regression equation.

$$Y = 25,703 + 4,094 (PC_1)$$

$$Y = 25,703 + 4,094 (0,231X_1 + 0,222X_3 + 0,258X_4 + 0,173X_5 + 0,225X_6)$$

$$Y = 25,703 + 0,945(X_1) + 0,910(X_3) + 1,055(X_4) + 0,706(X_5) + 0,920(X_6)$$

The results of this equation will be used in estimating the effect of the contribution of each technical production variable (X_i) to the catch of Mini Purse Seine fishermen in Moti District, Ternate City. Based on the previous principal component regression (PCR) equation, the multiple linear regression model on the original variables is obtained as follows.

$$Y = 25,703 + 0,945 (X_1) + 0,910(X_3) + 1,005(X_4) + 0,706(X_5) + 0,920(X_6)$$

Description:

Y = Catch (Kg)

X_1 = Ship Size (GT)

X_3 = Fuel (Litres)

X_4 = Engine Capacity (PK)

X_5 = Length of Fishing Gear (metres)

X_6 = Number of Crew (Number of People)

a. Ship Size (X_1)

The coefficient of 0.945 for variable X_1 can be represented that the catch of Mini Purse Seine is influenced by the size of the ship, where every increase of 1 GT of the ship is predicted to increase the catch by 0.945 Kg. The results of interviews with ship captains revealed that the waters in the South Halmahera area have the potential for abundant fish resources.

In the peak season, one or two net deployments are enough to get a significant catch if the small size of the vessel is the main barrier in accommodating the catch, so that the capacity of a larger vessel will allow more catches.

b. Fuel (X_3)

Based on the coefficient value of 0.910 for variable X_3 , it can be concluded that the use of fuel has a positive influence on the catch of Mini Purse Seine. Where every increase of 1 litre of fuel is predicted to increase the catch by 0.910 Kg.

This is due to the use of the amount of fuel directly related to the ship engine used so that with the increasing amount of fuel fishermen can increase engine power which can accelerate the speed of the ship in the process of looping the net so that it can keep up with the swimming speed of the fish. This finding is in line with Imanda et al. (2016) which states that the more the use of fuel, the greater the power of the ship's engine, so that the ship's speed is greater in looping the net and chasing schools of fish.

c. Engine Capacity (X_4)

The coefficient value of 1.055 for variable X_4 indicates that every increase in ship engine capacity by 1 PK can be predicted to increase the catch by 1.055 Kg or an increase of 1%. This indicates that vessels with larger engine capacity have an advantage in terms of speed, which allows the vessel to be more effective in catching fish. According to Wijopriono and Genisa (2003), vessels that have relatively high speed are able to keep up with or even exceed the swimming speed of fish. Thus, a faster vessel can increase the likelihood of fish being caught as it can chase and direct schools of fish into the net more efficiently.

d. Length Size of Fishing Gear (X_5)

The coefficient of 0.706 on variable X_5 indicates that the catch of Mini Purse Seine is significantly influenced by the length of the net. This means that every additional 1 metre of Mini Purse Seine net length is expected to increase the catch by 0.706 Kg. According to Rizwan and Aprilia (2011), fishing gear with a larger net length will produce a wider catch circle, so the possibility of fish caught in the circle will be greater. The average size of fishing gear used by Moti fishermen is less than 150 -250 metres so that if you increase the length of the fishing gear will increase the catch.

e. Number of children with special needs (X_6)

The coefficient value of 0.920 on variable X_6 indicates that the catch of Mini Purse Seine has a positive effect with the number of crew members. Where every additional 1 crew member is estimated to increase the catch by 0.920 Kg. Branch et al. (2006) explained that increasing the number of adequate crew members will facilitate fishing operations and have a positive impact on increasing catches. Mini Purse Seine fishing businesses in Moti District have a number of crew members ranging from 6 to 11 people, where each crew member has a specific task. If the number of crew members is insufficient, the fishing process will be disrupted, which will have an impact on the catch obtained.

4.7. Efficiency of Mini Purse Seine Business Unit in Moti District

Efficiency measurement is done by comparing output and input. Where input variables include the number of crew members, investment and total costs (fixed costs and variable costs), while output variables include profit and total production. The following is the actual data of input and output variables in the Mini Purse Seine fishery business unit.

Table 9. Actual Data of Input - Output Variables of Fishery Business Units

DMU	Variable Input			Variable Output	
	CREW (people)	Investment (Rp)	Cost (Rp)	Advantages (Rp)	Production (Kg)
1	8	550,000,000	319,424,333	87,075,666	26,700
2	10	530,000,000	355,737,142	128,262,857	32,000
3	8	480,000,000	309,901,142	120,448,285	28,330
4	8	375,000,000	274,563,326	166,186,673	28,850
5	8	520,000,000	344,180,000	57,820,000	25,600
6	8	295,000,000	265,567,333	73,432,666	22,200
7	6	27,000,000	141,590,000	132,910,000	18,300
8	6	27,000,000	141,590,000	149,419,000	19,400
9	11	520,000,000	350,267,727	104,982,272	29,950

Source: Primary Data (2024)

This research applies the Data Envelopment Analysis (DEA) methodology with the Variable Returns to Scale (VRS) approach. The selection of VRS model is based on the assumption that changes in inputs do not always result in proportional changes in output (Kirkley et al., 2001). Therefore, this model is suitable to be used to analyse efficiency in capture fisheries business because this model is flexible and allows to accommodate different business scales. The results of the calculation of efficiency values can be seen in the following table.

Table 10. Technical Efficiency Score of Mini Purse Seine Business Unit

Fleet Unit	DMU	Score (%)	Condition	Description
KM.Sonyinga	1	92,5	Amber	Approaching Efficient
KM. Tuanane	2	100,0	Green	Efficient
Nasau	3	98,2	Amber	Close to Efficient
Madiahi	4	100,0	Green	Efficient
2 Putri	5	88,7	Red	Not Efficient
Ninjani 02	6	83,2	Red	Not Efficient
Pribadi 01	7	94,3	Amber	Approaching Efficient
Fitria	8	100,0	Green	Efficient
Bula	9	94,2	Amber	Approaching Efficient

Source: Data Processing Results (2024)

The results of the analysis of the efficiency of the Mini Purse Seine fleet unit in Moti District, with the approach of peer business units as DMUs show variations in the level of efficiency. Where fleet unit 1 (KM. Sonyinga), fleet unit 3 (KM. Nasau), fleet unit 7 (KM. Pribadi 01) and fleet unit 9 (KM. Bula) achieved technical efficiency above 90%, which indicates that this unit is almost efficient but still has room for improvement on input variables (crew, operational costs and investment) and outputs (profit and production) used.

Fleet unit 2 (KM. Tuanane), fleet unit 4 (KM. Madiahi), and fleet unit 8 (KM. Fitria) each show perfect technical efficiency of 100%, the results of DEA analysis show that these three units are 'Efficient' and operate optimally without wasting resources, so that fishing operations are considered safe and fit for purpose. The achievement of the efficiency value of these three fleet units is influenced by the use of relatively small input variables but produces optimal output compared to other fleet units that are still below the technical efficiency standard.

Fleet unit 5 (KM. 3 Putri) and fleet unit 6 (KM. Ninjani 02), showed technical efficiency levels of 87.5% and 84.4% respectively, much lower than 100%, so based on the results of the analysis, both are categorised as inefficient, which indicates a waste of resources or inefficient operations that need to be improved. The reason these two fleet units have not achieved efficiency is due to the relatively small profits earned and high operating costs.

4.8. Estimation of Efficiency Improvement of Mini Purse Seine Fisheries Business in Moti District

Measurement of business unit efficiency in 9 units of the Mini Purse Seine fishery fleet shows that there are 2 fleet units that are still in an inefficient condition and 3 other fleet units are in a condition close to efficiency. Therefore, based on DEA analysis, improvements need to be made to the input and output variables. Projected changes in input and output variables in the Mini Purse Seine fisheries business unit that has not reached the efficiency level can be seen in the following table.

Table 11. Projected Improvement of Input and Output Variables

DMU	Input / output	Unit	Currently	Target	Potential Improvements
1	Number of crew members	People	8	8	0,00%
	Investment	Million/Rp	550	375	-31,82%
	Cost	Million/Rp	319,424,333	274,56	-14,04%
	Profit	Million/Rp	87,075,666	166,19	90,85%
	Production	tonne/Kg	26,7	28,85	8,05%
2	Number of crew	People	10	10	0,00%
	Investment	Million/Rp	530	530	0,00%
	Cost	Million/Rp	355,737,142	355,74	0,00%
	Profit	Million/Rp	128,262,857	128,26	0,00%
	Production	tonne/Kg	32	32	0,00%
3	Number of crew	People	8	8,00	0,00%
	Investment	Million/Rp	480	375	-21,87%
	Cost	Million/Rp	309,901,142	274,56	-11,40%
	Profit	Million/Rp	120,448,285	166,19	37,97%
	Production	tonne/Kg	28,33	28,85	1,84%

4	Number of crew	People	8	8,00	0,00%
	Investment	Million/Rp	375	375	0,00%
	Cost	Million/Rp	274,563,326	274,56	0,00%
	Profit	Million/Rp	166,186,673	166,19	0,00%
	Production	tonne/Kg	28,85	28,85	0,00%
5	Number of crew members	People	8	8	0,00%
	Investment	Million/Rp	520	375	-27,88%
	Cost	Million/Rp	344,18	274,56	-20,23%
	Profit	Million/Rp	47,82	166,19	247,53%
	Production	tonne/Kg	25,6	28,85	12,70%
6	Number of crew	People	8	7,54	-5,75%
	Investment	Million/Rp	295	295	0,00%
	Cost	Million/Rp	265,567,333	243,99	-8,12%
	Profit	Million/Rp	73,432,666	162,33	121,06%
	Production	tonne/Kg	22,2	26,68	20,17%
7	Number of crew	People	6	6	0,00%
	Investment	Million/Rp	27	27	0,00%
	Cost	Million/Rp	141,59	141,59	0,00%
	Profit	Million/Rp	132,91	149,42	12,42%
	Production	tonne/Kg	18,3	19,4	6,01%
8	Number of crew	People	6	6	0,00%
	Investment	Million/Rp	27	27	0,00%
	Cost	Million/Rp	141,59	141,59	0,00%
	Profit	Million/Rp	149,419	149,42	0,00%
	Production	tonne/Kg	19,4	19,4	0,00%
9	Number of crew	People	11	9,87	-10,32%
	Investment	Million/Rp	520	519,56	-0,09%
	Cost	Million/Rp	350,267,727	350,27	0,00%
	Profit	Million/Rp	104.982272	130,82	24,61%
	Production	tonnes/Kg	29,95	31,79	6,14%

Source: Data Processing Results (2024)

4.8.1. Projected Improvement of Investment Input Variables

The results of DEA analysis on 9 units of Mini Purse Seine fisheries business fleet in Moti District, found that there are three fleet units that are over-investment and need to reduce investment, namely fleet unit 1 (KM. Sonyinga), fleet unit 3 (KM. Nasau), and fleet unit 8 (KM. 3 daughters). The average investment value that needs to be reduced is from Rp. 369,333,333 to Rp. 322,000,000. The following is a graph of the actual and optimal investment value in 9 units of the Mini Purse Seine fishing business fleet.

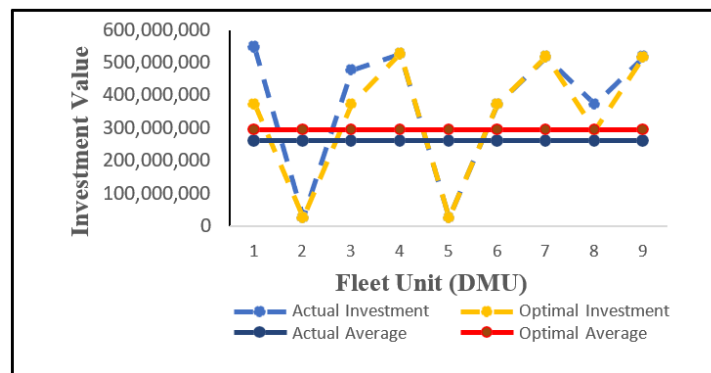


Figure 5. Graph of actual and optimal investment

Graph 6 shows that the difference between actual investment and the highest optimal investment occurs in fleet unit 1, (KM. Sonyinga) of Rp. 175,000,000, compared to other fleet units, this is because the use of engine capacity contained in fleet unit 1 is identified as excessive, namely 3 pieces with a capacity of 40 Pk. In addition, the use of 3 engines with a capacity of 40 pk also has an impact on high fuel consumption so that if it is not balanced with significant catches it will certainly have an impact on the level of efficiency, if it only has 2 engines it could be more efficient as done by fleet unit 4 (KM. Madiahi) which in this study is used as a benchmark for other fleet units that have not yet reached the optimal level of efficiency.

According to Tietze (2005), an increase in investment that is not on target, such as excess capacity in a fleet unit, can reduce the economic performance of fisheries. It can be said that a large investment value cannot guarantee the profit and catch obtained in the Mini Purse Seine capture fishery on Moti Island. Chang and Lee (2019) also explained that technological developments in fisheries do increase productivity, but too much investment in innovation without careful planning can reduce efficiency because costs increase faster than the results obtained.

4.8.2. Projected Improvement of Variable Input Operating Costs

The results of the DEA analysis show that there are 4 fleet units found to need a reduction in operating costs, namely fleet unit 1 (KM. Sonyinga), fleet unit 3 (KM. Nasau), fleet unit 6 (KM. Ninjani o2) and fleet unit 8 (KM. Fitria). The average total cost that needs to be reduced is from Rp. 278,091,223 to Rp. 259,047,667. The following is a graph of the actual and optimal total cost values.

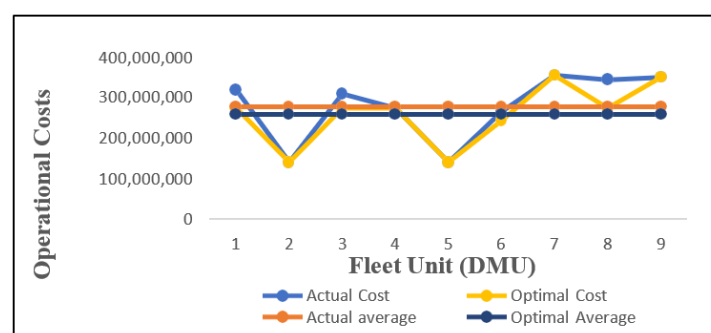


Figure 6. Graph of actual and optimised total cost

Excess operational costs in these 4 fleet units are caused by catches that are not comparable to operational costs incurred such as fuel and excessive consumption of fishermen in fishing operations. The difference between actual total costs and the highest optimal total costs occurred in fleet unit 8 (KM. Fitria) of Rp. 69,620,000 in one year.

The average value of fleet unit 8, on peer trip fuel costs of Rp. 3,200,000 and average consumption of Rp. 200,000 per trip while the average revenue earned in the regular season is Rp. 4,500,000 per trip. So, this indicates inefficiency in the fishing process in fleet unit 8, which is the most inefficient unit in the use of operational costs compared to other fleet units. This finding is in line with Putra (2019), which found that the operational cost variable has a negative and significant effect on the income of fishermen in Nusa Penida District with a coefficient value of -0.013 which means that the higher the operational costs incurred, it is predicted that it will reduce the income earned.

Lein and Setiawina (2018) also explained that high fishing costs will increase the costs that must be incurred in ongoing activities so that it will reduce the income earned by fishermen. To achieve efficiency in fleet unit 8, it is necessary to increase revenue by Rp. 1,500,000 or from Rp. 4,500,000 to Rp. 6,000,000, as is done by fleet unit 4 which in this study is used as a benchmark for other fleet units that are not technically efficient.

The largest expenditure for variable costs is the use of fuel oil with an average of 140 litres per trip with an average value of Rp 2,240,000 and will certainly continue to increase if fuel prices increase. Based on the results of interviews, the increasing use of fuel is caused by the placement of FAD points that are increasingly far from the coastal area of Moti Island, so that Mini Purse Seine fishermen mostly conduct fishing operations in the southern waters of Halmahera, namely the waters of Bacan, Kayoa and Makean.

4.8.3. Projected Improvement of Input Variables Number of crew members

Based on the results of the DEA analysis on the crew input variable, it was found that 2 fleet units need to reduce the number of crew members, namely fleet unit 9 and fleet unit 6, so it is necessary to reduce the number of crew members so that the revenue obtained is optimal. The following is a graph of improvements in the crew input variable.

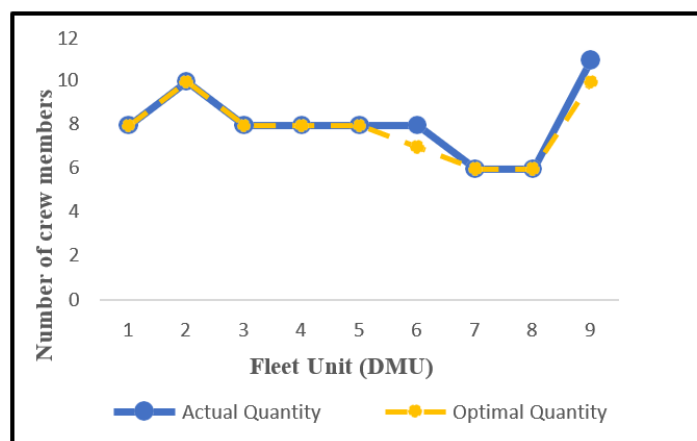


Figure 7. Graph of actual and optimal number of crew members

The results of the analysis show that in fleet unit 9, the number of crew members needs to be reduced by 1 person, from 11 people to 10 people. This is because the size of the fishing gear used by fleet unit 9, can be operated by only 10 people as is done by fleet unit 2, which has the same size of fishing gear but is only operated by 10 people and technically has reached optimal efficiency.

The results of research from Irham et al. (2022), found similar results where the variable number of crew members on Mini Purse Seine fishing gear in Tidore Islands City has a negative coefficient value of -4215.09 which indicates that if the number of crew members is reduced by one person, the amount

of catch production increases. In this study also occurred in DMU 9 and DMU 6, where if the number of crew members is reduced, it has the potential to increase the revenue earned.

4.9. Total Potential Improvements to the Fishery Business Fleet Unit

The potential improvement value achieved by the DMU if all of them run efficiently is called the total potential improvement. The total potential improvement for the Mini Purse Seine business unit is depicted in the form of a pie chart. The following is a picture of the total potential improvement in the Mini Purse Seine fishing business unit in Moti District, Ternate City.

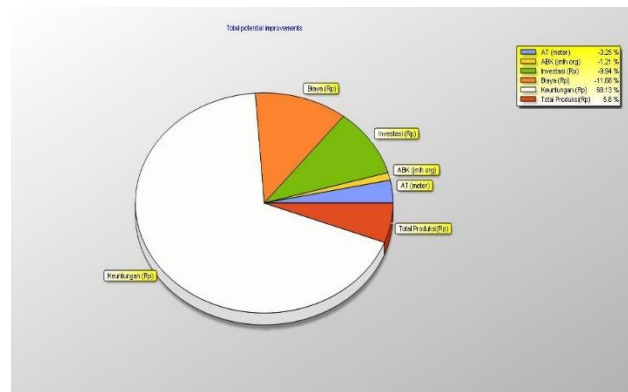


Figure 8. Total Potential Improvement Output-Input Value

Figure 8 shows that overall, in order for the fleet unit in the Mini Purse Seine fishery to be able to operate efficiently with 100% efficient conditions, improvements are needed on each input and output variable. Based on the results of the analysis, these improvements include an increase in profits by 68.13%, total production by 5.8%, or can reduce total costs by 11.68% and investment by 9.94%.

Efforts to minimise the use of inputs and maximise output are expected to be able to maintain or increase the value of output in the entire Mini Purse Seine fishery business fleet unit so that optimal conditions can be achieved. Several studies also recommend the same results to maximise output, namely income and production and minimise the use of inputs in the form of fixed and variable costs (total costs) and investment (Moniharapon et al., 2024; Tauda et al., 2021).

As additional information, based on the results of interviews at the research site, revealed that in previous years there were around 15-20 units of mini purse seine fishing fleet in Moti District. However, over time the number of these fleets has continued to decline, and currently only 9 fleets are still actively operating. This information is in line with the results of this study which identified 2 fleet units that are in an inefficient condition. If improvement efforts are not made immediately, these fleet units are expected to experience losses that could potentially lead to bankruptcy. Therefore, efficiency improvement measures are needed to ensure the sustainability of mini purse seine fisheries in Moti sub-district.

5. Conclusion

Based on the results of the study, it can be concluded that factors such as vessel size, duration of fishing, fuel, engine capacity, length of fishing gear, number of crew members, and number of trips together affect the catch of Mini Purse Seine fishers in Moti District by 82.6%, while the remaining 17.4% is influenced by other factors outside the research variables. Among these variables, vessel size, fuel use, engine capacity, gear length, and number of crew proved to have a positive and significant effect on catch. DEA analysis of 9 business units showed that 3 units were technically efficient, 4 units

were close to efficient, and 2 units were inefficient. Therefore, there is potential for improvement in the 6 inefficient units by reducing operational and investment costs and increasing production and profits. In particular, fleet units 9 and 6 need to reduce the number of crew members to achieve optimal efficiency.

For the government, it is expected to provide equal fuel prices for areas outside the core economic zone such as Moti Island and provide counselling or training to fishing communities regarding effective and efficient fishing techniques, management, and marketing of catches in order to improve the welfare of fishermen in Moti District, Ternate City. Meanwhile, for Mini Purse Seine fishers, it is recommended to revitalise fishing fleets and engines that have passed the technical and economic feasibility limits, so that the use of fuel becomes more efficient and the speed of the fleet can increase, thus contributing to the overall efficiency of the fisheries business.

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