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Technical Efficiency Analysis of Mini Purse Seine Fisheries in Jepara, Central Java

Siti Oftafia Wijayanti[1*], Nurani Khoerunisa[2], Dareen Nadea Rema[3]

[1]*Department of Capture Fisheries, Faculty of Fisheries and Marine Science, University of Diponegoro, Semarang, Indonesia,*
Jl. Prof. Jacub Rais, Tembalang. Kota Semarang. Jawa Tengah, Indonesia
[2]*Department of Fisheries, Faculty of Fisheries and Marine Science, University of Padjajaran, Jalan Raya Bandung Sumedang Km. 21, Jatinangor, Jawa Barat – 45365, Indonesia*
[3]*Department of Capture Fisheries, Faculty of Agriculture, Fisheries and Marine Science, University of Bangka Belitung, Jalan Raya Balunijuk, Desa Balunijuk, Kab. Bangka, Prov. Bangka Belitung – 33172, Indonesia*
Email: oktafiawijayanti@gmail.com

ABSTRACT

Catch density is one of the causes of fluctuations in mini purse seine fishery productivity in Jepara. The decreasing in catch production that needs to be balanced with production input management has an impact on the waste of input factors in fishing efforts. This study aims to calculate the technical efficiency value and the application of this calculation for the management of mini purse seine fisheries in Jepara. The average technical efficiency value of purse seine operations in Jepara Regency is 0.59% with suboptimal use of variable inputs of 0.94 for VIU1 (fuel), VIU3 (trip length), 0.97 and 0.96 for VIU4 (number of crew members). This condition is caused by increased competition between fishing gears, both between purse seine fishing gears and with other fishing gears, and very dynamic natural conditions related to information on fish abundance seasons, resulting in uncontrolled use of production inputs. VIU repair are needed because of excess capacity in the utilization of variable inputs. In order for VIU to reach an optimal level of using input variable, repairing for VIU made by reducing fuel input (6.00%), number of crew members (3.63%), and trip length (3.30%).

Keywords: *DEA; Jepara Regency; mini purse seine; technical efficiency*

1. Introduction

Jepara regency is the coastal area in the North Coastal of Java, where many local residents are employed as fisherman (DKP Jepara, 2023). The types of fishing gears that operated by fishermen in Jepara include mini trawls (85 units), mini purse seines (24 units), gill nets (388 units), hooks (176 units) and traps (1000 units). Mini purse seine has the highest productivity in Jepara regency that have fish target such as mackerel (Rastrelliger spp.), sardine (Sardinella spp.), scads (Decapterus spp.), and squids (Loligo spp.) (Pujianto et al. 2013).

Fishermen in Jepara operate the mini purse seine using two methods. They are called ngobor, because it uses a concentration lamp (bangkrak) during operation. The bangkrak is used when the boat stop to catch fish, that targeting is Scads (Pujianto et al. 2013). On the other side, it's called ngojek. The ngojek method primarily catch mackerels. The choice of method operation (ngobor/ngojek) is made by the captain of mini purse seine boat based on their expertise in identifying fish presence in the waters.

The fact that the Northern Coast of Java waters (Pantura) have become more densely populated is firther evidence by the degradation of fish resources (Suman et al. 2018). This condition is reflected in the productivity of mini purse seiine fisheries, which has experienced the largest decline in recent years (DKP Jepara 2023). Data showed that the total productivity of mini purse seine in Jepara, based on primary target fish, decreased by 36% in 2023, with production amount to 467,833 kg compared to 1,303,366 kg in 2018.

The Situation is exacerbated by the inability of fishermen to utilize input factors optimally. Input factors are dynamic and depend on the preferences of the biat owners. These input factors include fishing operations, boat dimension and crew size (Wicaksono and Effendi 2019). This condition indicated inefficiencies in mini purse seine fisheries in Jepara due to the failure of captain to determine the appropriate operating method for the mini purse seine. Suharno and Widayati (2015) added that inefficiency in input factors will result in suboptimal income.

To ensure the sustainability of mini purse seinefisheris in Jepara, recommendations are needed to optimize the using of input factors in mini purse seine operations. This study aims to: a) calculated technical efficiency (TE); and b) apply the calculation of TE for management of mini purse seine fisheries in Jepara.

2. Materials and Methods

2.1 Time and location of research

This research was conducted in Ujungbatu and Jobokuto Villages, Jepara Regency, Central Java Province as the base area for purse seine fishing in Jepara Regency. The data collection process was carried out from October to November.

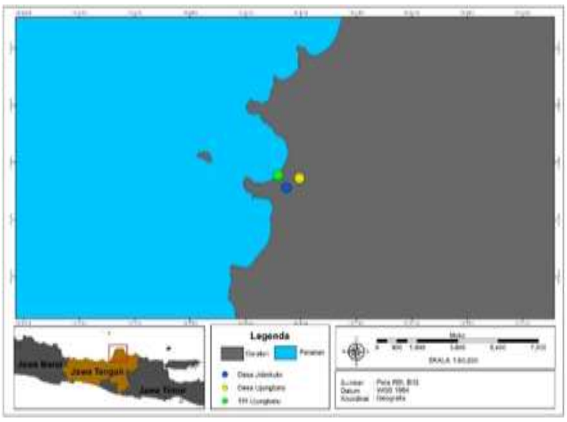

Fig 1 – Research Location

2.2 Data types and source

The data used in this research is secondary and primary data. Secondary data is in the form of production and effort data for the mini purse seine fishery in Jepara Regency for the 2015-2019 period. This data focuses on the three highest fish commodities caught by mini purse seines in Jepara, namely mackerel (Rastrelliger spp.), gliding (Decapterus spp.) and squid (Loligo spp.). while primary data comes from interviews with all owners of mini purse seine vessels in Jepara that are still actively operating.

Determining the technical efficiency value of purse seine vessels requires input and output data. The output data is catch data (3 dominant types of fish caught) by purse seine fishing gear (Hufiadi 2008: Budiarti et al. 2015). The dominant fish catch types were selected based on TPI Ujungbatu and DKP Jepara data for the last 5 years (2015-2019). Input data (Table 2) is divided into two, namely fixed input in the form of GT size and vessel PK power (Wiyono 2012) and variable input. Determination of this input data is based on several relevant studies which state a positive relationship between factor inputs and output (production) values which was tested statistically using CobbDouglas production factor analysis.

Input variable data are fuel supplies, fishing trips (Wiyono and Hufiadi 2014), net length, lamp power (Fatimah 2017) and number of crew members (Wicaksono and Effendi 2019). Input data was collected from respondent interviews using a questionnaire.

Table 1 - Iput Data Types

Fixed Input Data	Variable Input Data
Ship GT size	*Light Power (watts)*
Ship's PK Power	*Amount of fuel (liters)*
	Trip Length (hours)

Source: Research, 2020

2.3 The processing and analysis data

The technique for determining efficiency using Data Envelopment Analysis (DEA) suitable for application in fisheries production involves employing the variable returns to scale (VRS) model assumption (Fauzi and Anna 2005: Wiyono 2012). This approach is used to assess the efficiency of fishing gear operations and to determine the extent of effort that can be reduced or increased to achieve optimal production levels. Data is processed on a micro level monthly, with the decision-making unit (DMU) being the mini purse seine boats.

The data is analyzed using *linier programming* with *software* DEAP version 2.1 and followed by firther processing in *Microsoft Excel*. First, the vector output is defined as u and input vector as x. There are m outputs, n inputs and j observations (fishing units) along with fixed inputs (xf) dan variable inputs (xv). The output capacity and the value of perfect input utilization are calculated using the following equastions (Fare *et al.* 1994) :

$TE = \mathit{Max}\ \theta$

s.t. $\theta u_{jm} \leq \sum_{j=1}^{J} z_j u_{jm}$

$\sum_{j=1}^{J} z_j x_{jn} \leq x_{jn}$ $\quad n \in x_f$

$\sum_{j=1}^{J} z_j = 1$

$\sum_{j=1}^{J} z_j x_{jn} = \lambda_{jn} x_{jn}$ $\quad n \in x_v \quad \lambda_{jn} \geq 0$

$z_j \geq 0$

$m = 1, 2, \ldots, M$

$n = 1, 2, \ldots, N$

$j = 1, 2, \ldots, J$

assuming *j* represents the DMU (boats on a monthly basis over five years), there are 60 DMUs or *J* = 60 and *n* represents the inputs.

Explanation:

TE = technical efficiency of boat- j

θ = measurement value for each observation (≥ 1)

u_{jm} = output of boat- j, where m represents multiple outputs

x_{jn} = input of boat- j, consisting of n input (*multy input*), 2 *fixed input* (x_f) and 3 *variable input* (x_v)

λ_{jn} = level of utilization of the variable input-n

z_j = intensity of using variable input

Technical efficiency analysis is conducted by comparing the efficiency values between boats considered as decision-making units (DMUs). This involves determining the constant values for output (*u*), fixed input (*xf*), and variable input (*xv*) for each DMU, thereby deriving the fishing efficiency based on the utilization of variable input capacity (VIU). VIU is calculated by comparing optimal variables with actual variables (Budiarti et al. 2015). The interpretations are as follows:

- VIU < 1 : excess input in fishing, need to reduce input values
- VIU > 1 : insufficient input in fishing, need toincreaseinput values
- VIU = 1 : optimal capacity utilization (efficient)

3. Results and Discussion

3.1 Mini purse seine fishing demonstration in Jepara

The purse seine fishery in Jepara Regency is centered in Ujungbatu and Jobokuto Villages with a size of 16-21 GT and without the help of FADs. The lights used consist of a central light (Bangkrak light) and a transmitter light (ship light). Most fishermen still use diesel and gasoline for electricity, but some have started to switch to battery systems to reduce operational costs. The engines on purse seiners include propulsion engines, axle auxiliary engines, and light engines. Purse seine vessels in Jepara have propulsion engines measuring 120–150 PK per engine. Most fishermen in Jepara do not use GPS or fish finders in their operations; instead, they rely on the expertise of the skipper. Purse seines in Jepara are operated by around 15-40 members.

Purse seine fishing gear in Jepara consists of a top line, buoy, net, bottom line, weights, purse line, and seine ring. The catch of purse seine operations in Jepara consists of several types of fish, such as mackerel, juwi, kites, squid, tuna, mackerel, bentong, and others. The percentage of purse seine catches in Jepara, according to TPI Ujungbatu report data, includes mackerel (62.76%), kites (32.17%) and squid (5.07%). These three types of fish are the dominant catches of Jepara purse seines.

Purse seine operations in Jepara are carried out using two different operating methods, namely the ngobor and motorbike taxi methods. The ngobor operating method begins with preparing supplies and checking the machine and fishing equipment before leaving for the fishing location. The fishing location is usually found after 2-4 hours of travel, determined based on the experience of the captain, who is looking for calm, clear, and coral-free waters. After finding the right location, the ship's engines are turned off, the anchor is lowered, and the lights are gradually turned on. After waiting about 2 hours for the fish to gather, the set lights were turned off one by one, and the bangkrak were lowered into the water. Pecilen helps direct the bangkrak to the proper position. The setting process is carried out by reducing the net surrounding the bangkrak, which takes 10-30 minutes. Hauling is done by pulling the drawstring using a unique tool to form a bag, followed by lifting the boom and top rope using a pulley. This process takes 40-50 minutes, depending on the current and power available. The caught fish are then sorted with the help of a lamp for lighting.

The hunting operating method begins with preparing supplies and checking the ship's boss's engine and fishing gear. When looking for a fishing ground, the captain is at the bow of the vessel and only uses a flashlight for lighting while the ship continues to move. When the captain saw schools of fish on the surface, he gave directions to the crew to start setting, indicating that fishing ground had been found. The setting process involves lowering the mark buoy and net, with the boat looping the net until it is perfect. Hauling is done by pulling the drawstring using the pulleys and axle and lifting the top rope with a pulley. After that, the catch is taken, and the fish are sorted with the help of a lamp for lighting.

3.2 Dynamics of the mini purse seine fishing season in Jepara

The pattern of purse seine operations (trips) is not similar to the pattern of the squid season (Figure 2). Monthly fluctuations in trip and PMI show significant differences. Trip patterns decreased, while squid season patterns (IMP) increased, indicating a late response from fishermen, especially in May, July, October, and December. In contrast, an excessive reaction from fishermen was seen in February, March, August, and November. In January, April, June, and September, trip patterns tend to align with squid season.

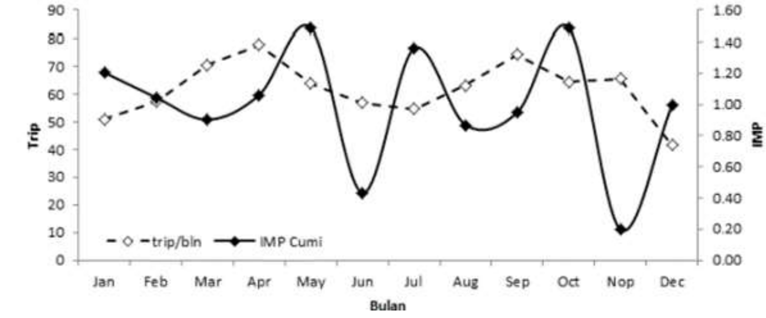

Fig 2 – Distribution of purse seine operating seasons (effort) on the IMP of squid

Purse seine trip patterns tend to follow the mackerel season, with optimal fisherman response seen in January-April, June-August, and October-December. Excessive response occurred in September, while in May, fishermen responded slowly even though mackerel stocks were abundant. In contrast to 10-15 years ago, May was known as the dry season for mackerel, now the catch season index increases from April to August carried out by PPN Pekalongan purse seine vessels (2002-2007) (Chodriyah & Hariati, 2010). In contrast to Bardiyanto and Kasa's (2012) research in the same year, the mackerel catch season index was known to increase from April to August. This statement correlates with the results of data processing, namely the PMI value > 1 from April to August, even though the trend is not increasing. Fish availability is influenced by factors such as hydro-oceanographic conditions, including high waves in the coastal waters of the north coast of Java, which causes the operating season value of purse seine vessels to tend to be low in December, January, July, and August (Malik, 2020). This situation results in the seasonal value of operating purse seine fishing vessels in that month tending to be smaller than in other months (Figure 3).

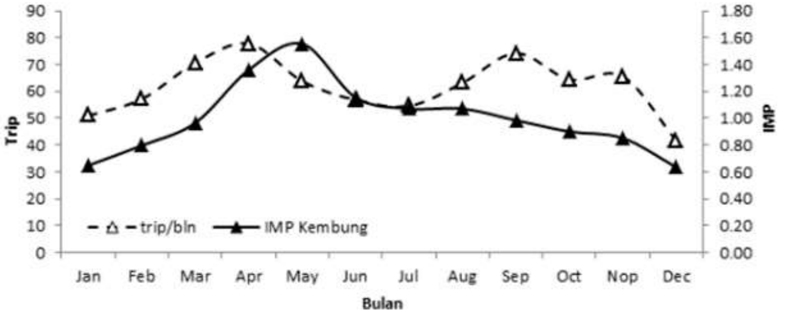

Fig 3 – Distribution of purse seine operating seasons (effort) on the IMP of mackerel

The operating patterns of purse seines in Jepara and the IMP of scads show similar fluctuations to those of mackerel, although the level of similarity is lower. The correct response from fishermen can be seen when trip patterns and the scads season move in rhythm, namely increasing in February and September and decreasing in June, September, and December. In contrast, differences in patterns occurred in other months, with fishermen responding excessively in January, August, and November and responding less quickly in May and July (Figure 4).

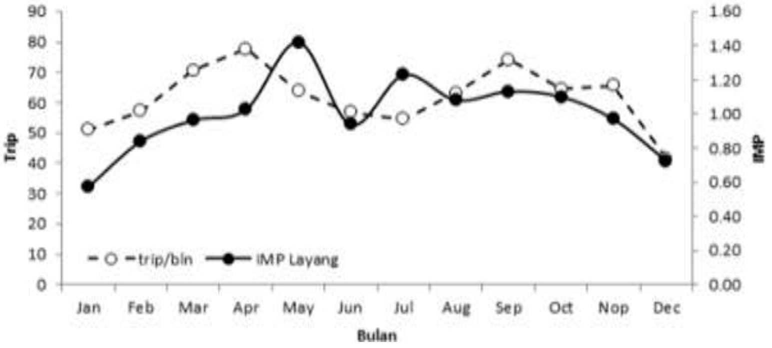

Fig 4 – Distribution of purse seine operating seasons (effort) on the IMP of scads

3.3 Technical efficiency of mini purse seine

The calculation of Technical Efficiency (TE) is presented in the form of monthly data (Figure 5). The diagram consists of TE values, VIU, and the impact of VIU improvements. The VIU values include fuel (VIU1), duration of the sea trip (VIU2), and number of crew members (VIU3).

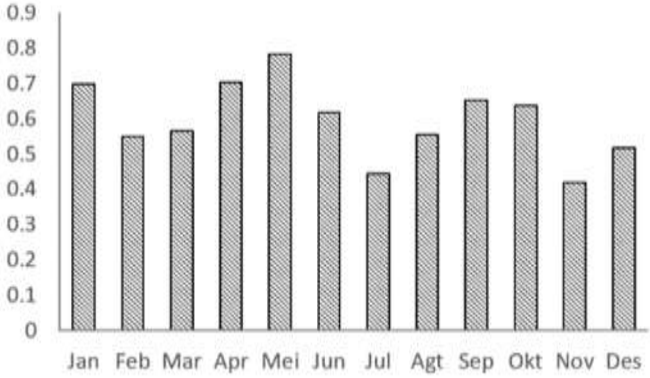

Fig 5 – The Value of TE Temporal in Every Month

Technical efficiency involves comparing input and output values (Wiyono and Hufiadi 2014), where inputs are factors that affect catch results. The estimated capacity utilization level for mini purse seine fishing gear in Jepara averages 0.59. The highest technical efficiency (TE) value was observed in May, while the lowest was in November. This indicates that there is inefficiency in the operation of the mini purse seine fishing business in Jepara.

Budiarti et al. (2015) noted that variable input factors have a greater impact compared to fixed input factors. Suharno and Widayati (2015) pointed out that in the North Coast (Pantura), the optimization of input use by small-scale fishermen has not yet been achieved. This statement is consistent with the research findings, which show that ring net fishing in Jepara experiences inefficiency each month. The greatest inefficiency in the use of variable inputs (VIU) is observed in fuel needs, followed by the number of crew members and trip duration (Figure 6).

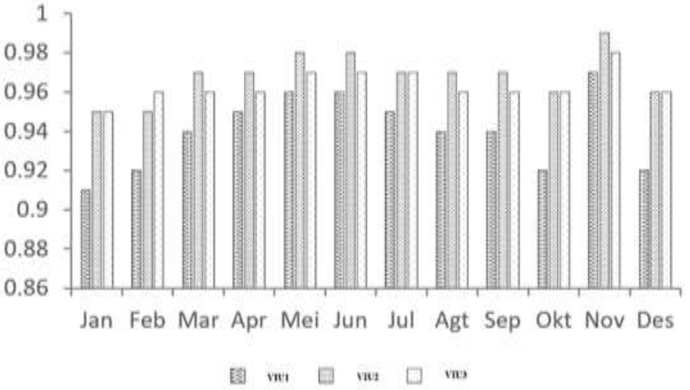

Fig 6 – The Value of VIU Temporal in Every Month

The suboptimal technical efficiency (TE) is a result of improper use of variable inputs. The three variable inputs—fuel, trip duration, and number of crew members—show signs of input surplus or overuse of variable inputs (VIU) each month. This is evident from VIU values less than 1 (VIU < 1), with average values being VIU1 (fuel) 0.94, VIU2 (trip duration) 0.97, and VIU3 (number of crew members) 0.96. This inefficiency in VIU is caused by increased efforts by fishermen due to the unpredictability of fishing seasons and fishing grounds. Inefficient use of inputs leads to a gap between actual production and optimal production. To achieve efficient ring net operations, efforts are needed to optimize the use of variable inputs to reach VIU = 1. Fatoni et al. (2017) reinforce that the inability of fishermen to utilize fishing inputs efficiently is evident from the excess use of inputs in each fishing process.

One of the causes of overcapacity is the waste of input factors, specifically VIU1 (fuel), VIU2 (trip duration), and VIU3 (number of crew members). Input waste occurs due to a positive relationship between inputs and outputs (fish catch production). Wicaksono and Effendi (2019) state that as the number of crew members increases, fish catch will also increase. This condition applies to fuel and trip duration inputs, even though mini purse seine production is expected to reach an optimal level to ensure the sustainability of fish resources and the operation of mini purse seines in Jepara. Therefore, this waste of inputs necessitates a reduction in the input factors used to achieve efficient conditions. Reducing input factors only occurs when input factors are not used optimally (VIU ≠ 1).

3.4 Operating management of mini purse seine in Jepara

Technical efficiency relates to the fishing season. The TE value tends to be lower in the western season compared to the eastern season. Therefore, the improvement in VIU is greater during the western season.

Table 2. Recommendation of Mini Purse Seine Operation in

Jepara Based on the Types of VIUs Operation and

Repair Methods

Month	**Fish Catching Season**			**Perbaikan VIU (%)**		
	Squid	**Mackerel**	**Scads**	**VIU1**	**VIU2**	**VIU3**
Jan	v			-8.85	-5.23	-4.86
Feb	v			-8.04	-4.74	-4.50
Mar				-5.98	-3.33	-3.56
Apr	v	v	v	-5.33	-2.89	-4.06
Mei	v	v	v	-4.29	-2.19	-2.79
Jun		v		-4.08	-2.08	-2.69
Jul	v	v	v	-5.16	-2.65	-3.19
Agt		v	v	-6.01	-3.30	-3.57
Sep			v	-5.99	-3.28	-3.56
Okt	v		v	-7.70	-4.43	-4.34
Nov				-2.96	-1.20	-3.19
Des				-7.56	-4.28	-4.28

Source: Research, 2020

The research conducted explains that every month, the operation of ring seines in Jepara experiences changes in the dominant fish species caught. Efficient ring seine operations, considering the suspected fish seasons and operating methods, will help minimize failures in ring seine operations by fishermen in Jepara Regency (Table 2). Knowing the fish seasons will impact the determination of ring seine operation methods, namely ngobor and/or ngojek, by the ring seine boat captains. Additionally, Zamroni et al. (2008) reinforced that mackerel fishing in the North Java waters is carried out by ring seine fishermen using a hunting method. This hunting process aligns with the ring seine operation method in Jepara Regency, which is ngojek. On the other hand, the ngobor method is used by ring seine fishermen in Jepara for catching fish other than mackerel. Thus, the use of both operation methods is recommended almost every month, with ngobor and/or ngojek methods used in April-May and July-August, ngobor method predominantly used in January-February and September-October, and ngojek method mostly used in June.

The VIU improvement represents the percentage of the reduction in VIU compared to the optimal VIU (VIU = 1). In January, to achieve optimal operation of the mini purse seine, a VIU improvement solution is needed by reducing fuel consumption (VIU1) by 8.85%, trip duration (VIU2) by 5.23%, and crew size (VIU3) by 4.86% from the usual conditions used by fishermen. This approach continues throughout the year, adjusting according to Table 2. Thus, with this alternative mini purse seine operation recommendation, information on the temporal efficiency of mini purse seine operations in Jepara for each month will be obtained.

The efficiency of mini purse seine operations in Jepara can be achieved by understanding fish seasons and using the appropriate inputs each month. This will help fishermen determine whether to operate the mini purse seine using the ngojek or ngobor method. Although external environmental factors may still influence operations, proper preparation for fishing can be managed by controlling the factors within reach.

Effective management of mini purse seine operations involves controlling the use of inputs through VIU improvement recommendations for input factors that are not yet optimal (Table 2) to minimize excess capacity and operational failures. Budiarti (2015) states that considering the fishing season index is one way to manage and prevent a decline in fish stocks in the wild. Wiyono and Ihsan (2014) add that regulating fishing effort is necessary to achieve responsible fishing efficiency.

4. Conclusion

The dominant fishing season for mini purse seine in Jepara occurs in April, May and July. The technical efficiency (TE) of mini purse seine fishing efforts inJepara is characterized by inefficiency, with values ranging from 0,942 to 0,78. The input variables (VIU) are not optimal, including fuel (0,94), crew size (0,96), and trip duration (0,97). Competition among fishing gear and dynamic weather condition constribute to the surplus inputs in operations. To improve the VIU and achive operational efficiency in purse seine, reductions are needed in the average input of fuel (8,85%), crew size (5,23%) and trip duration (4,86%).

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