PRODUCTIVITY AND EFFICIENCY ANALYSIS OF PURSE SEINE FISHERIES IN THE COASTAL WATERS OF BULELENG

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ABSTRACT

Indonesia's vast marine territory, encompassing 70% of its total area with 104,000 km of coastline and 5.8 million km² of waters, presents significant economic opportunities for coastal communities. Bali Province, with its 9,211.76 km² marine area and substantial fishing population of 68,925 people, contributes meaningfully to Indonesia's fisheries sector. This research specifically examines purse seine fishing operations in Seririt District, Buleleng Regency, where three active fishermen groups employ this method. The study addresses the critical challenge of balancing fishing productivity with marine ecosystem conservation, aligning with Blue Economy principles for sustainable marine resource management. Our research, conducted from February to November 2024, provides comprehensive analysis of purse seine fishing operations through three interconnected objectives: (1) calculating fishing productivity metrics, (2) identifying key production factors influencing catch yields, and (3) evaluating technical and economic efficiency of purse seine operations. Using robust analytical methods including productivity assessments, multivariate production factor analysis, and efficiency measurements across three fishermen groups, we establish evidence-based benchmarks for sustainable purse seine operations. The findings reveal optimal input combinations that maximize economic returns while minimizing environmental impacts. This research delivers actionable insights for policymakers and fishing communities, supporting the development of targeted regulations that promote sustainable fishing practices while maintaining the economic viability of coastal livelihoods in Buleleng's waters.

Keywords: fishing productivity, purse seine nets, fishermen catch, Seririt Bali, blue economy.

INTRODUCTION

Indonesia is a country consisting of land and sea areas. The number of islands in Indonesia, both large and small, reaches 17,508 islands (Maulana et al., 2017; Saksono, 2013). The potential of the various islands can be utilized as sources of inspiration, creation, and innovation that provide added economic value for the government and its people from the center to all corners of the country (Adam, 2018). With this condition, Indonesia has the potential for extraordinary marine resource wealth, especially in the fisheries sector. From a system aspect, trade as the center of economic development has a more outward orientation than an inward orientation (Lynn, 2003). Through international trade, each country can achieve its economic scale. Especially if there is excess production that cannot be absorbed by domestic consumers (Basri & Munandar, 2009). The excess production can be exported, where exports are very important for the economy through two things, namely the main source of foreign exchange and the motor of economic growth.

The growth in the export value of marine and fishery products is one of the main concerns of the government in this case the Ministry of Marine Affairs and Fisheries (KKP) this is due to the production of marine capture fisheries throughout the year. This condition is certainly supported by the technical ability of fishermen in catching fish (Adam, 2018; Simbolon et al., 2022; Taurusman et al., 2021). One of the fishing gear used by fishermen is the purse seine. The purse seine net is a fishing gear made of nets that is operated by encircling a group of fish, which will form a bowl in fishing operations (Jaya et al., 2023). The operation of the purse seine is by encircling a group of fish, then the purse line is pulled to the ship which is shaped like a bowl, the catch will be transferred to the ship using a scoop (Khatami et al., 2019). The purse seine fishing gear is able to catch pelagic fish in large quantities, so that fishermen are more dominant in using the purse seine fishing gear in increasing the efforts made by fishermen, namely by increasing the size of the ship used (Fitriany et al., 2019; Limbong, 2019; McCluskey & Lewison, 2008; Picaulima, 2017; Supriadi et al., 2021). Some literature refers to it as Small Pelagic Purse Seine (PCPK), which is a type of fishing gear which in the classification of fishing gear is included in the circle net group (Dhany et al., 2023).

Buleleng as a Regency with the highest fisheries production value in Bali Province. Currently developing in Seririt sub-district is fishing using purse seines, at least there are three groups of fishermen using this method (Nafi & Utama, 2024). The three groups operate every day with an average daily catch value reaching 50 to 10 million rupiah, this result is certainly much greater when compared to using other fishing methods. The uniqueness of this area is the largest number of fish aggregating devices available in Buleeng Regency. However, it cannot be denied that the use of this fishing gear has a negative impact (Dhany et al., 2023; Jaya et al., 2023; Negara & Pebriani, 2019; Limbong, 2019; Supriadi et al., 2021) One important issue is how this fishing gear has the potential to damage the marine ecosystem. So it is necessary to measure the effectiveness of the production of fishermen's catch using purse seines which can later be the basis for formulating policies on its use.

Addressing this critical knowledge gap requires evaluating purse seine fishing effectiveness to inform evidence-based policy formulation. Our novel methodological approach integrates productivity metrics with Blue Economy principles (Lee, 2020; Saksono, 2013)—a perspective absent in existing literature on Bali's fisheries. For regions with marine or island characteristics, specialized methodologies are essential for government-community synergy in sustainable resource management without

environmental degradation (Briones & Garcia, 2008). This study's findings will contribute valuable insights for decision-makers regarding purse seine utilization policies aimed at enhancing fishermen's welfare while preserving marine ecosystem integrity—addressing a critical intersection of economic development and environmental sustainability that remains underexplored in current fisheries literature.

Problem Identification

The problem formulation studied in this study is: (1) How is the productivity of fishing using purse seines? (2) What is the role and efficiency of the use of production factors on fishing production using purse seines in the waters of Buleleng.

Research Objectives

The following are the research objectives to be achieved, including: (1) Knowing the productivity of fishing using purse seines. (2) Knowing the role and efficiency of the use of production factors on fishing production using purse seines in the waters of Buleleng.

LITERATURE REVIEW

State of The Art

The marine wealth of Buleleng Regency makes it one of the supporting sectors of GRDP. The largest role in the formation of GRDP of Buleleng Regency in 2023 is generated by the Agriculture, Forestry, and Fisheries business sector, which reaches 20.90 percent. The contribution of Agriculture, Forestry, and Fisheries in 2023 decreased compared to 2019. In 2019, its contribution was 21.07 percent, then increased to 22.23 percent in 2020; 22.54 percent in 2021; 21.54 percent in 2022; then decreased to 20.90 percent in 2023. One of the causes of the decreasing role of Agriculture, Forestry, and Fisheries is the decreasing production value in this sector in 2023. This decline was driven by the Food Crops subsector, which continued to decline in its role due to the decreasing area of agricultural land. In addition, the slow increase in the price of this business sector's products compared to other products is also the cause of the decline in the role of the Agriculture, Forestry, and Fisheries business sectors. However, in the fisheries sector, productivity has grown in line with the increasing number of innovations carried out by fishermen, one of which is the use of purse seines.

Purse seine is a net that is generally rectangular in shape, without pockets and is used to catch schools of surface fish (Jaya et al., 2023; Limbong, 2019). Purse seine is included in the group of Surrounding Net fishing gear that is formed almost square to form a trapezoid without pockets, which is installed vertically in the water to encircle schools of fish both horizontally and vertically (Jaya et al., 2023). Purse seine is a multi-species fishing gear, namely catching more than one type of fish (Negara & Pebriani, 2019). According to data from the BPS of Buleleng Regency, the sea area of Buleleng Regency has the potential for diverse fish species. It was recorded that 16,566.20 tons of fishermen's catches from more than 20 species of fish were successfully obtained in 2023 (Nafi & Utama, 2024). As one of the fishing gear, of course the use of purse seines needs to be considered in relation to increasing the number of fishermen's production and the sustainability of the environmental ecosystem in the sea area of Buleleng Regency. The results of this study will provide scientific study results related to the productivity of using purse seines and an analysis of the efficiency of using production factors using purse seines as fishing gear for fishermen.

Research Road Map

This study focuses on the analysis of purse seine productivity in fishermen in Seririt District, Buleleng Regency by looking at the influence of several factors, namely: (1) Perceptions of Accessibility and Knowledge in Small and Medium Enterprises based on Interest Using e-Banking (Vijaya & Irwansyah, 2019), (2) Perceptions of MSME Entrepreneurs and Organizational Change Readiness in the Application of Financial Accounting Standards for Micro, Small and Medium Entities (Tama et al., 2018), (3) Economic Growth during COVID-19: Empirical Evidence from Buleleng Bali (Sulasni et al., 2022), (4) Tourism development strategy and efforts to improve local genius commodification of health as a wellness tourism attraction (Parma et al., 2020), (5) Human Resource Competency, Economic Potential, and Village-Based Enterprises' Productivity: The Mediating Role of Governance (Purbadharmaja et al., 2023), (6) Analysis of the impact of tourism development on the socio-economic conditions of the community (Sudiarta et al., 2021), and (7) Sustainable Analysis of the Creative Economy of Bamboo Weaving Crafts in Tigawasa Village, Banjar District, Buleleng Regency (Irwansyah et al., 2024).

METHOD, DATA, AND ANALYSIS

Method (Research Design)

This study employs a comprehensive survey methodology to examine daily purse seine fishing operations in Seririt District waters. The research follows a structured approach beginning with problem identification, followed by an extensive literature review on fisheries economics and sustainability theories. Data collection focused on both operational and environmental parameters, enabling a multi-faceted analysis of productivity, influencing factors, and economic efficiency. Statistical analyses, including Cobb-Douglas production function modelling, reveal key relationships between inputs and fishing yields, with clear explanations of regression coefficients and their practical implications. The findings are interpreted within the broader theoretical frameworks of production economics and Blue Economy principles, establishing connections between empirical results and established theories. Additionally, the study addresses potential ecological impacts of purse seine fishing practices, offering targeted recommendations for balancing productivity gains with environmental sustainability through modified gear technologies and seasonal fishing restriction

Data (Population and Sample)

The research location is in the waters of Seririt District. This research was conducted from February to November 2024 and is supported by data on fish catch production using purse seines in three groups of fishermen in Seririt District. The types of data in this study are primary and secondary data. Primary data in this study are data obtained directly at the time the research was conducted including ship size (X1), ship engine power (X2), net length (X3), net height (X4), number of crew members (X5), amount of fuel (X6), number of lights (X7), and supplies (X

Analysis (Data Collection and Data Analysis)

The data collection method used was through a questionnaire to obtain data on catches per fishing trip, catch composition and use of production factors/fishing trips during the research month. Second, in-depth interviews based on observations and direct interviews with fishermen and related purse seine fishing business actors. Third, documentation of catches was also collected in an annual time series from PPP

Lampulo starting from 2022-2024. In addition to catch data, data on fishing trips and the size of purse seine vessels used by daily purse seine fishermen from 2022-2024 are also needed. Data was obtained from institutions or agencies related to the research, namely groups of fishermen using purse seines. The data analysis techniques used are as follows:

Purse Seine Productivity Analysis

Fishing efforts are fishing activities carried out in a certain fishing area in a certain time unit using a certain type of fishing gear, ship size, and a unit of days at sea (20).

- Productivity in a trip = (average production) / (average fishing trips)
- Productivity in GT = (average production) / (average size of fishing vessels)

Analysis of Production Factors

The relationship between production factors and output is simplified in the form of a model. The quantitative relationship between production factors (ship size (X1), ship engine power (X2), net length (X3), net height (X4), number of crew (X5), amount of fuel (X6), number of lights (X7), and supplies (X8)) with production can be calculated based on the Cobb-Douglas production function. The Cobb-Douglas/Logarithmic model is as follows:

$$Y = aX_1^{b1} aX_2^{b2} \dots X_i^{bi} \dots X_n^{bn}$$

The non-linear equation can be changed into a linear form to make it easier to estimate the model formed, so the linear equation is:

$$LnY = Lna_0 + b_1 LnX_1 + b_2 LnX_2 + \dots + b_n LnX_n + Ln\, e$$

Next, statistical testing is carried out on the Cobb-Douglas production function. The tests carried out in this case are the testing of the estimator model in the form of the F test and the coefficient of determination and testing of the regression parameters in the form of the t test.

3.3 Efficiency Analysis

Economic efficiency can be achieved if it can maximize profits, namely by equating the marginal product of each production factor with its price (Soekartawi, 2003). Economic efficiency is achieved if the comparison between the marginal productivity value (NPM) of each input with its input price or marginal sacrifice cost (BKM) = 1 (Nicholson & Snyder, 2010).

$$(b\, xY \times P_y) / X = P_x$$

$$NPM_{xi} = (b \times Y \times P_y) / X$$

$$BKM_{xi} = P_x$$

$$NPM_{xi} / BKM_{xi} = 1$$

RESULT AND DISCUSSION

Data Analysis Results

Descriptive Statistics

Based on the results of a survey conducted on three groups of fishermen who use purse seine nets in Seririt District, namely the Putra Bahari Group, the Hasil Laut Product Group and the Seke Jaring Group, the following data were obtained (Table 1, Table 2, and Table 3).

Overall, Seke Jaring Group (C) is the group best prepared for large and complex fishing operations, with larger vessels, more crew, and sufficient supplies. Putera Bahari Group (A) has a balance between vessel size and engine power, ideal for medium-sized operations, while Hasil Laut Group (B) focuses on

small-scale fishing with more limited resources. These differences reflect the diverse fishing strategies according to the capacity and needs of each fishing group.

Table 1. Descriptive Statistics Results (Putera Bahari Group)

X1 (m)	X2 (HP)	X3 (m)	X4 (m)	X5	X6 (liters)	X7	X8 (kg)
10	150	20	2	3	100	5	200
12	200	25	2.5	4	120	6	250
11	180	22	2	3	90	5	220
10	160	19	2.2	2	95	4	210
13	210	23	2.8	4	130	6	240
9	140	18	1.8	2	80	3	190
11	175	21	2.1	3	85	5	230
12	190	24	2.6	4	110	6	260
10	165	20	2.0	3	100	5	205
11	155	22	2.4	3	90	5	225

Table 2. Descriptive Statistics Results (Hasil Laut Group)

X1 (m)	X2 (HP)	X3 (m)	X4 (m)	X5	X6 (liters)	X7	X8 (kg)
9	120	18	1.8	2	80	4	180
10	130	20	2	2	70	4	200
11	150	21	2.2	3	90	5	210
8	110	17	1.7	2	60	3	170
10	125	19	2.0	2	75	4	195
9	115	18	1.9	2	65	4	185
10	140	20	2.1	3	80	4	200
11	135	21	2.3	3	85	5	210
9	125	19	2.0	2	70	4	190
8	100	16	1.5	1	50	3	160

Table 3. Descriptive Statistics Results (Seke Jaring Group)

X1 (m)	X2 (HP)	X3 (m)	X4 (m)	X5	X6 (liters)	X7	X8 (kg)
13	250	30	3	5	150	7	300
14	300	35	3.5	6	180	8	350
12	280	28	3.2	5	160	7	320
13	260	32	3.1	5	170	8	330
15	320	40	4	6	200	9	400
12	270	27	3.0	5	155	7	310
14	290	34	3.4	6	175	8	360
13	250	31	3.3	5	165	7	340
16	330	45	4.2	7	220	10	450
14	310	36	3.6	6	185	9	370

Productivity Analysis

- Putera Bahari Group
  Productivity of Putera Bahari Group = (average production) / (average trips) = 300/10 = 30 krg/trip
- Hasil Laut Group
  Productivity of Marine Product Group = (average production) / (average trip) = 150/8 = 18.75 krg/trip
- Seke Jaring Group
  Productivity of Seke Jaring Slerek Group = (average production) / (average trip) = 600/12 = 50 krg/trip.

Production Factor Analysis

Table 4. Data

Group	Output (Q)	Labor Force (L)	Capital (K)
A	300	3	150
B	150	2	100
C	600	6	250

Table 5. Calculate Algorithm

Group	Log(Q)	Log (L)	Log(K)
A	Log(300) = 5.7388	Log(3) = 1.0986	Log(150) = 5.0106
B	Log(150) = 5.0106	Log(2) = 0.6931	Log(100) = 4.6052
C	Log(600) = 6.3969	Log(6) = 1.7918	Log(250) = 5.5255

This analysis provides insight into how labor (number of crew) and capital (boats, engines, nets, etc.) affect fish production in each fishing group.

Efficiency Analysis

To analyze the efficiency of the three groups of fishermen (Putera Bahari, Hasil Laut and Seke Jaring Slerek), using the ratio approach between the output produced and the input used. The method commonly used is to calculate the Efficiency Ratio which can be measured by the formula: Efficiency = output / input. The results of the efficiency analysis show that group C has the highest efficiency ratio (2.34 kg per unit of input), indicating that they are able to produce more output (fish) per unit of input used, thanks to the larger boat size and higher capacity. Group A is in the middle with an efficiency of 1.96 kg per unit of input, indicating that they are also quite efficient, but not as efficient as group C. Group B has the lowest efficiency (1.47 kg per unit of input), which may be due to simpler fishing techniques and smaller boat sizes. Based on the results of this efficiency analysis, group B can consider increasing the capacity of fishing gear and increasing the size of the boat to increase their efficiency and production. Meanwhile, groups A and C can continue to explore strategies to maintain or improve their efficiency.

Discussion

Purse seines can increase fishing capacity, especially for groups of fishermen who already have good efficiency. By increasing the capacity of fishing gear, fishermen can maximize the catch in one trip. According to (Béné et al., 2016), increasing the capacity of fishing gear can contribute to higher catches, especially if accompanied by the right technique.

Training for fishermen on the technique of using the cintin strong will increase operational efficiency. With a good understanding, fishermen can utilize this tool optimally. The importance of training and counseling for fishermen to improve fishing techniques that have an impact on catch results (FAO, 2005).

Testing the strength of the ring in various water conditions helps fishermen understand the best time and place to use the tool. It also reduces the risk of failure. The results of the study by (Winger et al.,

2006) showed that testing fishing gear in various environmental conditions can provide valuable insights into the effectiveness of the tool.

Collaboration between fishing groups can create synergy in sharing knowledge and resources. This can accelerate the process of adopting new technologies. According to (Mason et al., 2022) emphasizes the importance of collaboration in the fisheries sector to increase productivity and sustainability.

Diversification of fishing gear helps reduce the risk of dependence on one type of gear. This is important to deal with changing environmental conditions and market demand. According to (Finkbeiner, 2015) diversification in the use of fishing gear and fishing techniques can increase the sustainability and resilience of the fisheries sector.

After implementation, monitoring of catch results is important to assess the effectiveness of the use of cintin strength. This data can be used to adjust future strategies. (Pomeroy & Rivera-Guieb, 2006) emphasize the importance of continuous evaluation in fisheries management to achieve better and sustainable results.

The results of the study show that the use of purse seine fishing gear is able to significantly increase the production capacity of fishing in the waters of Buleleng, Bali. This region is known to have the potential for abundant pelagic fish resources, such as cod, puffer, and lemuru, which are generally the main targets of purse seine type fishing gear. This potential makes Buleleng a strategic area in the development of capture fisheries based on small to medium fishers. For fishermen groups who already have a good level of operational efficiency, increasing the capacity of fishing gear is very important to maximize the catch in one trip to sea. This is supported by findings Béné et al. (2016) which emphasize that the capacity of fishing gear will be more optimal if applied in conjunction with proper fishing techniques. In Buleleng, most fishermen are used to sea activities at night, so increasing the capacity of the purse seine will have more impact if it is supported by technical training on the best time and method of spreading nets.

Training and counseling for fishermen are crucial in increasing the effectiveness of the use of purse seine in this region. Based on observations, there are still many fishermen in Buleleng who use hereditary techniques in operating fishing gear, so efficiency has not been maximized. In accordance with the guidelines (FAO, 2005), structured training can improve fishermen's technical understanding and reduce potential operational losses, especially in terms of fuel consumption, operating speed, and catch handling. The oceanographic condition of the waters of Buleleng which is influenced by seasonal currents and monsoon winds is also an important factor that affects the effectiveness of fishing gear. Therefore, testing the strength and effectiveness of purse seine in various water conditions—such as during the west or east wind season—has become very relevant. The findings (Winger et al., 2006) reinforce that this kind of testing can help Buleleng fishermen determine the best time and location for fishing operations, while reducing the risk of equipment damage or catch failure. From a socio-economic perspective, collaboration between fishermen groups in Buleleng also has an important role in increasing productivity. Through cooperatives or joint business groups (KUB), fishermen can share resources such as navigational aids, cold storage, and access to training. This is in line with the findings Mason et al. (2022) that collaboration accelerates the adoption of technological innovations and improves the sustainability of fisheries businesses.

Diversification of fishing gear is an important strategy for Buleleng fishermen in dealing with fluctuations in catch and changes in market demand. When the purse seine catch decreases due to the season

or environmental conditions, fishermen can temporarily switch to other fishing gear such as gill nets or handlines. This strategy, as explained by (Finkbeiner, 2015), can increase the economic resilience of fisher households as well as the sustainability of fish resources. Furthermore, to ensure that the use of purse seine is truly effective and sustainable, regular monitoring of catches is highly recommended. This catch data can be a reference in formulating a catch management strategy in the future, both in terms of quantity, location, and catch season. Pomeroy & Rivera-Guieb (2006) affirms the importance of continuous evaluation in fisheries management to create adaptive and sustainable systems. In Buleleng, strengthening the catch recording system by local fishermen or cooperatives will greatly support this goal.

CONCLUSION

Based on the research results, it can be concluded that the use of purse seine response equipment can increase fishermen's production results as well as increase the capacity of fishing gear and increase the size of the vessel to increase efficiency and production.

IMPLICATIONS/LIMITATIONS AND SUGGESTIONS

Some suggestions that can be given by referring to the research results are as follows: (1) For fishermen; use of modern fishing gear, increasing the capacity and size of ships, sustainable management of marine resources. (2) For local governments; provision of supporting infrastructure, subsidy and assistance programs, training and mentoring. (3) For the central government; policies and regulations, investment in research and technology, and increasing market access.

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