Bioeconomic modeling of resource management strategy for purple-spotted bigeye (*Priacanthus tayenus*) at Tegalsari Coastal Fishing Port

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Abstract. The primary fishing activity in Tegal City is centered around the Tegalsari Coastal Fishing Port, which holds significant potential with an estimated fishing capacity of 27,718,682 tons in 2021. Among the valuable catches in this region is the purple-spotted bigeye (*Priacanthus tayenus*), typically caught using Danish seine nets. This study aims to assess the status, utilization, cultivation, and management approaches concerning purple-spotted bigeye resources at Tegalsari Coastal Fishing Port, employing a bio-economic perspective. The research methodology involves descriptive analysis, with data collected through purposive sampling of 100 respondents for bioeconomic analysis and 30 respondents for SWOT analysis. The analysis reveals that the maximum sustainable yield (MSY) for purple-spotted bigeye amounted to 5,030,756 kg from 1,041 fishing trips, while the maximum economic yield (MEY) was 4,943,170 kg from 904 fishing trips, and the open access equilibrium (OAE) saw a catch of 2,304,830 kg across 1,808 fishing trips. Optimal profitability is observed in the MEY scenario, yielding IDR 44,915,090,819, compared to IDR 43,877,326,458 under MSY conditions, while OAE results in no profit. The allowable exploitation level for purple-spotted bigeye at Tegalsari Coastal Fishing Port stands at 2,935,162 kg, with an average exploitation rate of 58% and an effort level of 124%, indicating overfishing of this resource. The analysis positions the management strategies within Quadrant I (Strength-Opportunity), focusing on averting overfishing, enhancing supporting infrastructure development for the fishing port, and improving the economic conditions of fishermen.
Key Words: b, MEY, MSY, OAE, SWOT.

Introduction. The Law Number 45 of 2009 requires the Minister of Maritime Affairs and Fisheries to determine the potential and allocation of fishery resources in the fishery management areas (FMAs) in Indonesia. The Ministerial Regulation Number 33 of 2019 on FMA 712 encompasses the waters of the Java Sea, which include the regions of South Kalimantan, Central Kalimantan, East Java, Central Java, West Java, Jakarta, and Banten. According to Hikmayani et al (2017), the demersal fish resources in FMA 712 are fully exploited, indicating that caution should be exercised in their exploitation.

Tegalsari Coastal Fishing Port in Tegal City produced 27,718,682 tons of all types of fish with a production value of IDR 138,593,414,000 in 2021. The Law No. 45 of 2009 on Fisheries in Article 7 paragraph (1) letter C reads "In order to support the policy of management of fishery resources, the Minister shall determine the number of allowable catches in the fishery management area of the Republic of Indonesia". According to the Minister of Maritime Affairs and Fisheries Decree No. 19 of 2022, the allowable catch of demersal fish in FMA 712 is set at 72,932 tons, with a utilization rate of 110%.

Purple-spotted bigeye (*Priacanthus tayenus*) is a bycatch of Danish seine landed at Tegalsari Coastal Fishing Port. Tegalsari Coastal Fishing Port is a landing site for purple-spotted bigeye fish that makes an ideal site for data collection in research on bio-economics. The results of this research are expected to positively contribute to the knowledge on biology and economics, particularly regarding the economic value of purple-spotted bigeye in Tegalsari Coastal Fishing Port. The knowledge later serves as the basis for sustainable management decisions. The Decree of the Minister of Maritime Affairs and Fisheries of the Republic of Indonesia No. 19 of 2022 on the Estimation of Potential Fish Resources, Number of Allowable Fish Catches, and Level of Fish Resource Utilization states that the utilization rate of demersal fish resources in FMA 712 (marine waters North Java) is 110%. Tegalsari Coastal Fishing Port, located on the north coast of Java, is one of the fishing ports that utilizes Danish seine. The high productivity of Danish seine makes it the primary gear used by fishermen in their fishing activities.

The production of purple-spotted bigeye, a demersal fish, increased by 260.13% over five years (2018 to 2022) at Tegalsari Coastal Fishing Port (2022). Bioeconomics is essential in resource management because fisheries have traditionally focused on maximizing catch, while the economic activities in fisheries are complex and involve various production inputs (Dafiq et al 2019). The high selling price of purple-spotted bigeye drives large-scale fishing, including in the Tegalsari Coastal Fishing Port area. Despite this, studies on bioeconomics and management strategies related to purple-spotted bigeye landed at Tegalsari Coastal Fishing Port have not been conducted. Therefore, research is needed to provide an overview of the management of purple-spotted bigeye resources at Tegalsari Coastal Fishing Port, specifically using Danish seine fishing gear, through a fisheries bioeconomics approach.

Materials and Method

Description of the research sites. This research was conducted in Tegalsari Coastal Fishing Port, Tegal City, Central Java from October to November 2023. Tegalsari Coastal Fishing Port is located at the coordinates 109°07'43” E 6°50'58” S as shown in the Figure 1.

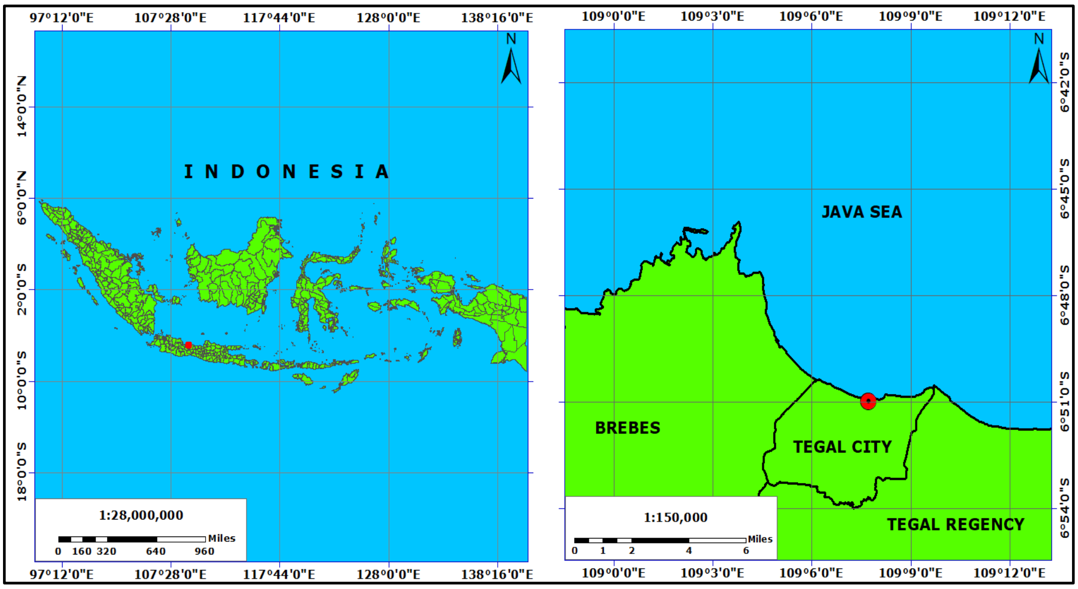

Figure 1. Research locations.

Data collection and data analysis. In this descriptive research, surveys and direct observations were carried out in the field. Purposive sampling was used to select 100 respondents based on the following criteria: (a) the fishing fleet is based in Tegalsari Coastal Fishing Port, (b) the fishing gear used is Danish seine, (c) the main catch or bycatch includes purple-spotted bigeye, and (d) the respondents are directly involved in fishery use and management at Tegalsari Coastal Fishing Port. The data of this research underwent SWOT analysis. Of the total samples, 30 persons were interviewed, consisting of 20 fishermen, 4 purple-spotted bigeye collectors, 3 representatives from Tegalsari Coastal Fishing Port (including 1 Coordinator of Harbor Master Operational, and 2 Staff of Harbor Master Operational), and 3 representatives from fisheries monitoring officer. Data collection techniques included observation, interviews, documentation, and literature review. Primary data were gathered through interviews, while secondary data included production and production value, number of fishing gear, and number of fishing fleets at Tegalsari Coastal Fishing Port over the past five years.

Catch per unit effort (CPUE) analysis. The formula for calculating CPUE is:

$$CPUE_i = \frac{C_i}{E_i} \quad (1)$$

where: $CPUE_i$ = catch per effort of the i year (kg $trip^{-1}$);
C_i = number of production for year i (kg $year^{-1}$);
E_i = effort of the i year (trip $year^{-1}$).

Gordon Schaefer model and Fox model. Bioeconomic is an analysis of the exploitation of capture fishery resources that combines the economic parameters that influence the fishing industry and the biological factors that determine fish production and supply. The static approach of the Gordon-Schaefer model was used in determining the maximum sustainable yield (MSY), maximum economic yield (MEY), and open access equilibrium (OAE).

Fox (1970) proposed an alternative model for fish populations in which intrinsic growth follows a logarithmic model. The exponential model assumes that the population will not go extinct and considers the population as the number of individual fish. Therefore, the modification of the Schaefer model introduces an exponential relationship between CPUE and fishing effort. The formulas for the Gordon-Schaefer and Fox analyses are shown in Table 1.

Table 1

Gordon-Schaefer model and Fox model

Model	*MSY*	*MEY*	*OAE*
Gordon Schaefer model			
Catch	$a^2/4b$	$aE_{MEY} - b(E_{MEY})^2$	$aE_{OAE} - b(E_{OAE})^2$
Effort	$a/2b$	$p\alpha - c)/(2pb)$	$(p\alpha - c)/(pb)$
TR	C_{MSY} x p	C_{MEY} x p	C_{OAE} x p
TC	c x E_{MSY}	C x E_{MEY}	C x E_{OAE}
Profit	$TR_{MSY} - TC_{MSY}$	$TR_{MEY} - TC_{MEY}$	$TR_{OAE} - TC_{OAE}$
Fox model			
Catch	$E_{MSY}.e^{(a-b.E)}$	$e^{(a-b.E)}$	$c(\ln c - \ln p - C)/(pb)$
Effort	$1/b$	$(\ln c/pb - a)/b$	$\ln c - \ln p - C/b$
TR	C_{MSY} x p	C_{MEY} x p	C_{OAE} x p
TC	c x E_{MSY}	c x E_{MEY}	c x E_{OAE}
Profit	$TR_{MSY} - TC_{MSY}$	$TR_{MEY} - TC_{MEY}$	$TR_{OAE} - TC_{OAE}$

Source: Wijayanto et al (2016). Note: C = catch results (kg $year^{-1}$); effort = catch effort (trips $year^{-1}$); TR = total revenue (IDR per year); TC = total expenditures (IDR per year); a = intercept; b = slope; c = cost (IDR); p = price (IDR per kg); e = exponential number, namely 2.718.

Total allowable catch (TAC). Based on the Decree of the Minister of Maritime Affairs and Fisheries No. 19 of 2022, the allowable catch of groundfish in FMA 712 is 50% of the total estimated potential of existing demersal fish resources. The following formula was used in the calculations:

$$TAC = 50\% \times MSY \quad (2)$$

where: TAC = total allowable catch (kg);
MSY = maximum sustainable yield (trip).

Level of utilization and level of effort. The following formula is used for the exploitation rate of purple-spotted bigeye:

$$\text{Utilization rate} = \frac{\text{Production}}{\text{TAC}} \times 100 \quad (3)$$

$$\text{Effort rate} = \frac{\text{Effort}}{E_{MSY}} \times 100 \quad (4)$$

where: Production = production of fish (kg);
TAC = total allowable catch (kg);
effort = number of fishing attempts (trip).

***Analysis of purple-spotted bigeye resource management strategy**.* SWOT analysis is an analysis on the Strengths, Weaknesses, Opportunities and Threats of certain object. SWOT analysis is used for strategic planning in solving a problem. Rangkuti (2006) proposed several stages of SWOT analysis; a) data collection - evaluation of data on internal and external factors; b) data analysis - creating an internal-external matrix and a SWOT matrix; C) decision making.

To construct an external-internal matrix for managing purple-spotted bigeye in Tegalsari Coastal Fishing Port, begin by segmenting column 1 into internal factor evaluation (IFE) and external factor evaluation (EFE) sections, reflecting the arrangement of management factors. Next, assign weights to each factor in column 2, ranging from 0.0 (no impact) to 0.20 (very strong). In column 3, rate each factor's importance from 1 (not important) to 4 (very important). Multiply the weight by the rating to populate column 4. Sum the total weighting scores for internal and external factors. These totals can guide the creation of a SWOT matrix, facilitating the formulation of management strategies tailored to purple-spotted bigeye in Tegalsari Coastal Fishing Port.

In accordance with Yahya et al's (2013) guidance, the stages involved in determining weights, ratings, and scores for data analysis through SWOT analysis are explained as follows:

a). The weight is obtained by dividing the total number of respondents' responses by the total number of respondents' responses to either IFAS or EFAS, and then adding the total number of responses to either IFAS or EFAS:

$$\text{Weight} = \frac{\text{Factor weight}}{\text{Total weight of all factors}} \quad (5)$$

b). The rating is obtained by dividing the total number of respondent responses by the number of respondents, then rounding to the nearest unit:

$$\text{Rating} = \frac{\text{Sum of ratings of all respondents}}{\text{Number of respondents}} \quad (6)$$

c). The score for the SWOT analysis is obtained by multiplying the weight by the rating:

$$\text{Score} = \text{weight} \times \text{rating} \quad (7)$$

Results

***Bioeconomy analysis**.* The costs used in the purple-spotted bigeye in business include fixed costs and variable costs. Fixed costs consist of investment costs, depreciation costs, and maintenance costs. Meanwhile, operating costs consisting of supplies, diesel, clean water, and ice are included in the variable costs. Based on the data presented, the average fixed cost per trip was IDR 2,132,650 and the average variable cost each effort was IDR 12,986,823. The average total cost of catching purple-spotted bigeye per trip at Tegalsari Coastal Fishing Port was IDR 15,119,473.

Income from fishing effort is the income obtained from the auction process or direct purchase. Profit is the gap between income and expenses. Danish seine fishermen conduct fishing operations four times annually, yielding an average income of IDR 22,366,500 during the lean season, IDR 31,751,160 in the regular season, and IDR 35,975,500 in the peak season, with expenses amounting to approximately IDR 15,105,136 per trip^{-1}. Meanwhile, the profit earned by the fishermen during the lean season is IDR 7,261,364, in the regular season IDR 16,646,024 and in the peak season IDR 20,870,364. The following are the income and profit obtained from purple-spotted bigeye fishing business at Tegalsari Coastal Fishing Port for each trip based on the season (Table 2).

Table 2

Average total cost and revenue and profits

Description of total costs		*Average total cost per trip (IDR per trip)*	
Fixed cost		2,132,650	
Variable costs		12,986,823	
Amount		15,119,473	
Types of seasons	*Average income (IDR per trip)*	*Production (IDR per trip)*	*Profit (IDR per trip)*
Lean	22,366,500	15,105,136	7,261,364
Regular	31,751,160	15,105,136	16,646,024
Peak	35,975,500	15,105,136	20,870,364

CPUE analysis is used to determine the relationship between the amount of fish production caught and the fishing effort at a given time. The catch per unit of fishing effort fluctuated in 2017 to 2022. In 2018, the highest CPUE reached 9829.17 kg $trip^{-1}$, indicating a high catch despite relatively low fishing effort. Conversely, the lowest CPUE value of 466.28 kg $trip^{-1}$ was recorded in 2017. The CPUE values for purple-spotted bigeye, obtained from production data and fishing trips at Tegalsari Coastal Fishing Port are presented in Figure 2.

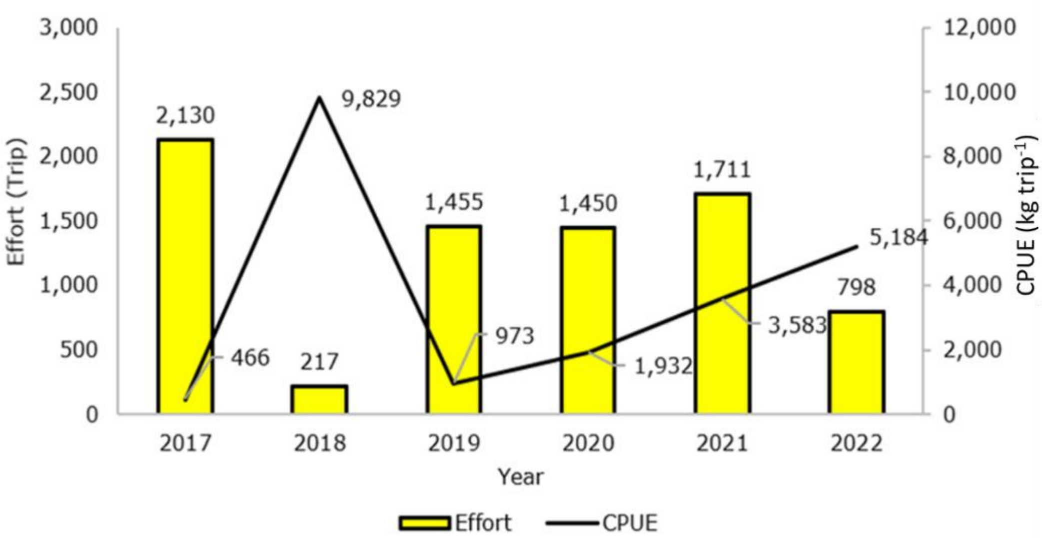

Figure 2. The progress of CPUE and fishing effort.

The bio-economic analysis measures the bio-economy of the purple-spotted bigeye resources in Tegalsari Coastal Fishing Port using the Gordon-Schaefer model analysis and the Fox model analysis as shown in Table 3, Figure 3 and Figure 4. The analysis conducted in the same year using the Schaefer model consistently indicated that the actual effort of 1,294 trips year-1 exceeded the MSY effort of 1,041 trips $year^{-1}$, resulting in a utilization rate of 58% and an effort rate of 124%. This conclusion finds further support from statistical analysis, where the R^2 value of the Schaefer model (R^2 = 0.824) surpassed that of the Fox model (R^2 = 0.736). Thus, indicating the Schaefer model's superior accuracy in elucidating the relationship between catch and effort. Consequently, the bioeconomic analysis revealed that the Fox model inadequately reflects field realities, whereas the Schaefer model provides a more relevant depiction of production, effort, and exploitation levels.

Table 3

Bioeconomic analysis of the Gordon-Schaefer model and the Fox model

Model	*MSY*	*MEY*	*OAE*
Gordon Schaefer model			
Catch (kg year^{-1})	5,030,756	4,943,170	2,304,830
Effort (trip year^{-1})	1,041	904	1,808
TR (Rp year^{-1})	59,607,346,098	58,569,581,736	27,308,981,835
TC (Rp year^{-1})	15,730,019,641	13,654,490,917	27,308,981,835
Profit (Rp year^{-1})	43,877,326,458	44,915,090,819	0
Fox model			
Catch (kg year^{-1})	3,764,964	3,681,852	2,194,525
Effort (trip year^{-1})	710	570	1,721
TR (Rp year^{-1})	44,609,501,759	43,624,743,925	26,002,024,904,53
TC (Rp year^{-1})	10,717,942,353	8,609,927,346	26,002,024,904,53
Profit (Rp year^{-1})	33,891,559,406	35,014,816,580	0

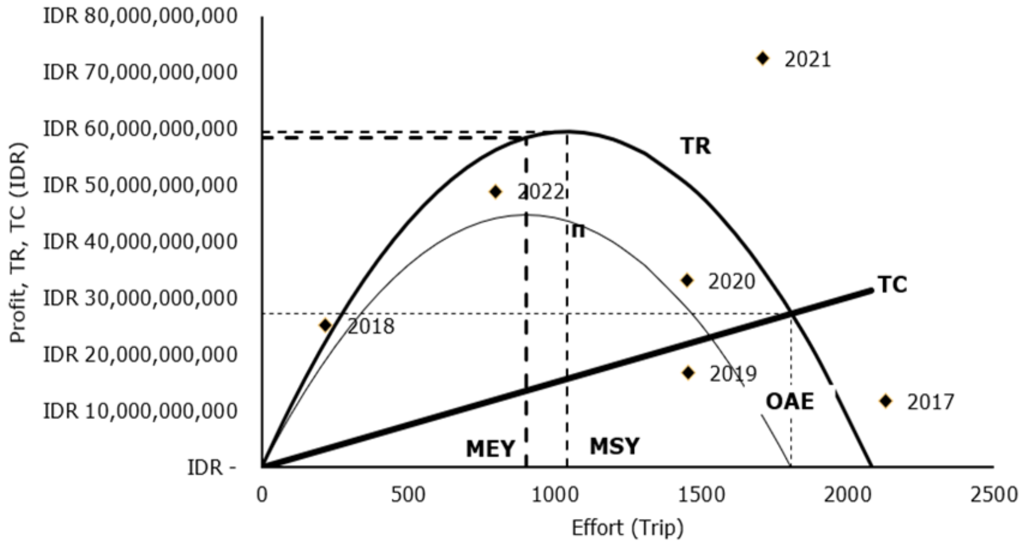

Figure 3. Gordon-Schaefer model.

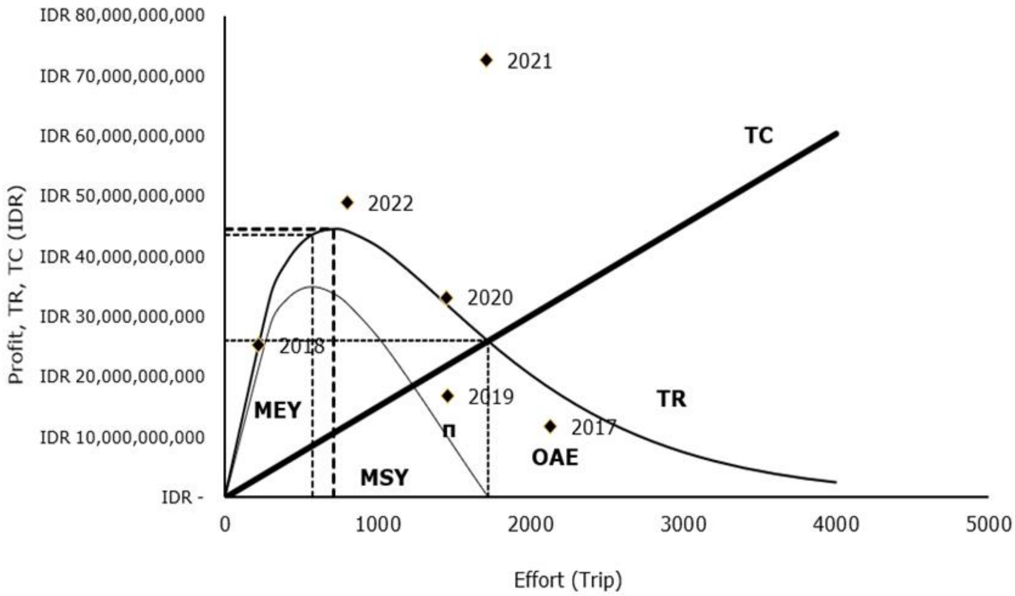

Figure 4. Fox model.

Utilization rate measures the extent to which fishery resources are being utilized in a given water body. Utilization rate is calculated based on the percentage of catches in a time series with a value of the number of allowed catches at 80% of the value of the optimum sustainable potential (C_{MSY}) for the last 5 years. The fishing effort level is determined by dividing the actual fishing effort by the fishing effort under MSY conditions (C_{MSY}). The outcomes of computing the exploitation and cultivation levels of purple-spotted bigeye are outlined in Table 4.

Table 4

Level of utilization rate and effort rate

Year	*Actual production*	C_{MSY}	*Actual effort*	*Utilization rate*		*Effort rate*	
				Schaefer	*Fox*	*Schaefer*	*Fox*
2017	993,166	5,030,756	2,130	20%	26%	205%	300%
2018	2,132,930	5,030,756	217	42%	57%	21%	31%
2019	1,415,437	5,030,756	1,455	28%	38%	140%	205%
2020	2,801,675	5,030,756	1,450	56%	74%	139%	204%
2021	6,131,026	5,030,756	1,711	122%	163%	164%	241%
2022	4,136,740	5,030,756	798	82%	110%	77%	112%
		Average		58%	78%	124%	182%

***Management strategy**.* The SWOT analysis performed in this research determined the appropriate strategy for managing purple-spotted bigeye resources landed in Tegalsari Coastal Fishing Port. The analysis was conducted by identifying internal and external factors that could influence purple-spotted bigeye resources in Tegalsari Coastal Fishing Port. Internal factors include strengths and weaknesses, while external factors include opportunities and threats. Thirty (30) respondents with adequate understanding of the field conditions were involved as experts. Three respondents represented port employees, three from Marine and Fisheries Resources Surveillance of Tegal City, twenty from fishermen, and four from fish collectors for the study.

Internal factors are the influence the management of purple-spotted bigeye resources that arise from within the environment, while external factors are factors that influence the management of purple-spotted bigeye resources from outside the environment. These factors were obtained by analyzing the condition of purple-spotted bigeye resources and conducting interviews with port staff. The assessment of factors that can influence the management of purple-spotted bigeye resources was carried out by analyzing issues or problems, conditions and potential of the resource. Identification of internal and external factors for the management of purple-spotted bigeye resources was also carried out based on SWOT data analysis.

The Grand Strategy Matrix was used as the reference in determining the coordinate location of quadrant the Y and X. Calculations were employed to determine the score for each factor on the external and internal factors (Table 5), while the alternative strategies are presented in Table 6.

Table 5

Internal and external factors score

Code	Information	Value		
	Strength	*Weight*	*Rating*	*Score*
S1	The availability of fish auction as a party that provides marine catch, one of which is purple-spotted bigeye;	0.12	3.90	0.45
S2	The location of the port is strategic, it is located on the north coast route which it is easy to reach and has fairly wide distribution access to various regions and major cities throughout Java Island;	0.12	3.83	0.44
S3	The potential of human resources (fishermen) is adequate, where fishermen already have fishing experience for more than 3 years;	0.11	3.87	0.42
S4	Effective use of Danish seine gear;	0.11	3.83	0.42
S5	Availability of large areas of land to support fishing activities.	0.11	3.37	0.37
	Amount	0.57	18.80	2.10
	Weakness	*Weight*	*Rating*	*Score*
W1	The control fleet is not yet optimal and legal sanctions have not yet been taken against vessel owners;	0.10	2.13	0.21
W2	Low level of education of fishermen;	0.09	1.87	0.18
W3	Space for loading and unloading catches is limited compared to the increasing number of fishing vessels docking at Tegalsari Coastal Fishing Port;	0.08	1.43	0.12
W4	Inadequate waste management infrastructure, garbage is still being dumped at the pier, resulting in pollution of the Tegalsari Coastal Fishing Port pier;	0.08	1.37	0.11
W5	Lack of access to capital causes fishermen to pay less attention to the condition of the fishing gear and infrastructure used, and encourages fishermen to fish in areas that are not fishing grounds.	0.08	1.27	0.10
	Amount	0.43	8.07	0.72
	Number of internal factors	1.00	26.87	2.82
	X coordinates		1.38	
	Opportunity	*Weight*	*Rating*	*Score*
O1	The production of purple-spotted bigeye is not yet optimal, where in the last 5 years there has been fluctuation, both decreasing and increasing production yield with an average of 2,935,162 tons;	0.12	3.83	0.46
O2	The demand for purple-spotted bigeye continues to increase with a stable selling price of IDR 12,000 kg^{-1};	0.12	3.33	0.40
O3	The expansion of fishing areas includes FMA 711, FMA 718 and FMA 572;	0.12	3.40	0.40
O4	There is a fish sales market and fish processing factory around the port with a building area of 784 m^2;	0.12	3.77	0.46
O5	The network of investors is very wide and has increased every year, with the recorded use of street vending kiosks (9 m^2) of 100 units, self-financing kiosk (9 m^2) of up to 40 units, for fish processing industry up to 15 units, fish meal processing industry 1 unit, shophouses and offices (50 m^2) 35 units, fish packing kiosk (18 m^2) 30 units, government packing kiosk (18 m^2) 4 units, traders in the old TPI 32 units and another building (multi-purpose building) 3 units.	0.11	3.30	0.37
	Amount	0.59	17.63	2.09
	Threat	*Weight*	*Rating*	*Score*
T1	There are conflicts over fishing areas with fishermen from different fishing bases;	0.06	2.30	0.14
T2	The mesh size is not appropriate because there are still many purple-spotted bigeye caught, which are not suitable to be caught with a length of 13 cm;	0.08	2.00	0.16
T3	It is happened *tragedy of common* by catching more than the production of 5,030,756 kg $year^{-1}$ and an effort of 1,041 trips;	0.08	2.30	0.19
T4	Purple-spotted bigeye resources in the Indonesian Ocean are decreasing in number as seen from the smaller size of fish caught, the fishing area is moving further north and the determination of fishing areas is still limited;	0.10	1.83	0.18
T5	Overfishing with a utilization rate of 58% in 5 years (2017-2022).	0.09	1.80	0.17
	Amount	0.41	10.23	0.83
	Number of external factors	1.00	27.87	2.92
	Y coordinates		1.25	

Table 6

The alternative strategies

Type of strategy	*Alternative strategies*
SO strategy	SO1. The regional government will work together with the central government to increase supervision, equip monitoring facilities, and infrastructure in optimizing the potential of purple-spotted bigeye to prevent the occurrence of overfishing to produce biologically and economically sustainable catches (S1, S2, O1); SO2. Utilize experienced human resources supported by adequate facilities and optimize infrastructure in fisheries activities by implementing central, regional and government programs towards the development of supporting infrastructure (S3, S5, O1); SO3. Expand fishing, marketing, and fish processing networks by establishing cooperation among government, investors, and fishermen's associations for fishery businesses (S4, O2, O3, O4, O5).
WO strategy	WO1. Cooperate with the central government in monitoring and demarcating territorial waters by utilizing a marketing network and distribution of catch that is wide enough to prevent the occurrence of overfishing (W1, O1, O2); WO2. Develop knowledge and apply modern technology to fishing gear and fleets thereby they can maximize the number of catches within demand requirements (W2, W3, W5, O2, O3); WO3. Conduct education and training in cooperation with the central government by utilizing a fairly large marketing network to be able to build and develop waste management infrastructure (W4, O5).
ST strategy	ST1. Control the catch production and net mesh size by monitoring the catch of purple-spotted bigeye landed at Tegalsari Coastal Fishing Port (S1, S2, S4, T2, T3, T5); ST2. Enforce strict regulations and sanctions for violations in the management of purple-spotted bigeye resources (S3, T1, T3, T4); ST3. Strengthen the development of facilities and means for fishing activities (S3, S5, T5).
WT strategy	WT1. Coordinate between fishermen and local government and stakeholders related to determine the distribution area of purple-spotted bigeye resources (W2, W5, T1, T4); WT2. There is strict law enforcement and sanctions against the entry of foreign fishermen, thereby minimizing illegal fishing and non-environmentally friendly fishing gear operating (W1, T2, T3, T5); WT3. Improve and develop port facilities and infrastructure and improve waste management as well as conduct outreach and guidance on the Tegalsari Coastal Fishing Port (W2, W3, W4, T4).

Discussion. Managing finances or costs is essential for fishing businesses to maintain a balance, as highlighted by Listiana et al (2013), who emphasize the need for sustainable profits from fishing efforts. The costs associated with operating a business focused on purple-spotted bigeye comprise fixed and variable costs. Fixed costs include investment depreciation and maintenance expenses, while variable costs encompass operational expenditures like supplies, diesel, water, and ice. Fixed costs remain constant irrespective of production activity (Mangi et al 2007; Hapsari & Fitri 2016). Total costs comprise investment and maintenance depreciation alongside fixed expenses for each trip, with fluctuations influenced by variable costs tied to activity volume and market prices. Fishermen aspire to earn income and profits to sustain their livelihoods, which constitute the sum of variable and fixed costs. However, only 1.96% of total purple-spotted bigeye catch contributes to fishermen's earnings, thereby impacting total operating costs. Profit levels and operating expenses significantly affect fishermen's incomes (Karningsih et al 2014), as indicated by Noufal et al (2019), who underscores the composition of total costs, comprising fixed and variable expenses inherent in business operations.

The income from fishing fluctuates across different seasons, with the fishing season playing a pivotal role in determining fishermen's earnings. Typically, income during the lean season tends to be lower compared to both normal and peak seasons.

The revenue derived from purple-spotted bigeye fishing is contingent upon factors like trip duration and the prevailing season. Seasonal closures, as highlighted by Pipitone et al (2000) and Macusi et al (2021), are often implemented to safeguard demersal resources during critical stages of their life cycles, thereby bolstering fish biomass. Calculating the annual income for each season involves multiplying the income per trip by the number of trips conducted within that season. Income per trip is calculated by multiplying the quantity of catches by the market price per kilogram. As noted by Kholis et al (2017), fishermen's earnings are significantly impacted by the fishing season, particularly during lean periods characterized by diminished catch volumes, leading to higher selling prices due to limited fish stocks.

During the lean season, the catch often fails to offset the fishing costs, leaving many fishermen without profits or even facing losses from selling their catch. Profit margins for fishermen vary across seasons, contingent upon the catch and associated expenses. When fishing costs are low and income is high, profits soar; conversely, when costs are high and income is low, profits dwindle or losses occur. Profitability is determined by deducting total fishing costs from total income. As noted by Buton et al (2022), net profit, or net income, represents the disparity between total revenue or sales proceeds and total costs or expenses over a specific timeframe. This metric indicates a business's capacity to cover operational expenses or all incurred costs, with higher net profits reflecting greater operational efficiency. A positive net profit signifies the viability of the fishing venture, demonstrating its ability to cover both short-term and long-term expenses.

In this context, deterministic bio-economic modeling tools have gained widespread recognition for analyzing and deriving optimal and sustainable management policies for open-access fisheries (Wijayanto et al 2020; Dutta et al 2021). Bioeconomic model can be used to predict the impact of alternative strategies in fisheries management (Sobers 2010; Wijayanto et al 2019). The bio-economic analysis used to analyze the bio-economy of purple-spotted bigeye resources in Tegalsari Coastal Fishing Port was the Gordon-Schaefer model analysis. The Gordon-Schaefer model is a type of fisheries analysis that can be easily applied to fisheries management in order to maintain sustainability and obtain maximum economic benefits in the use of fisheries resources. The Gordon-Schaefer model focuses on the relationship between fishing effort from both biological and economic perspectives. The Gordon-Schaefer method can identify and adapt the most appropriate fisheries management model to conserve fish stocks that provide the best benefits in fisheries, especially capture fisheries. The static bioeconomic analysis using the Gordon-Schaefer method was conducted utilizing the linear regression approach to determine intercept and slope values. Through this analysis, values for MSY, MEY, and OAE were determined.

The results of processing the bioeconomic analysis for purple-spotted bigeye reveal that the catch value under MSY conditions surpasses that of MEY, resulting in a higher total revenue (TR) for MSY compared to MEY. Additionally, the fishing effort required for MEY is lower than that for MSY. At the OAE point, where total revenue (TR) equals total expenditure (TC), the profit is zero, indicating a break-even point in purple-spotted bigeye fishing business. This equilibrium occurs when the catch does not proportionally match the fishing effort, or when fishing effort is high but catch is low, resulting in zero profit. The profitability under MSY conditions exceeds that under MEY conditions, primarily due to the abundance of purple-spotted bigeye resources in the area. However, factors such as fishing effort and high discount rates may incentivize resource exploitation, leading to OAE and degradation, ultimately resulting in overfishing. Zainuddin (2018) stated the urgency of controlling fishing effort to ensure it does not exceed the optimal level for MEY conditions to maximize economic rent. While reducing fishing effort may decrease fishermen's income, it is crucial to implement policies such as fishing effort regulations, size limits, and conservation of potential areas to sustainably manage fish resources.

As seen in Table 3, MSY conditions have reached a maximum point in catch results (catch) amounting to 5,030,756 kg year^{-1} with fishing effort of trips 1,041 year^{-1} and profits amounting to IDR 43,877,326,458. MEY's condition reached its maximum point in catch (kg) amounting to IDR 4,943,170 year^{-1} and fishing effort (trips) was carried out 904 times a year with profits obtained amounting to IDR 44,915,090,819. OAE conditions are obtained at the time of catch (catch) amounting to 2,304,830 kg year^{-1} and fishing effort was carried out 1,808 times with a profit of IDR 0.00.

MSY represents the highest quantity of fish that can be harvested sustainably without jeopardizing the long-term health of the fish stock. This yield is determined by factors such as fishing effort and catch. Research findings indicate that at the point of MSY in the Gordon-Schaefer model, the maximum catch (C_{MSY}) is calculated to be 5,030,756 kg year^{-1}, with a corresponding fishing effort (E_{MSY}) of 1,041 trips per year. This means that the catch of 5,030,756 kg represents the maximum sustainable catch of purple-spotted bigeye. Any production exceeding the C_{MSY} value can have detrimental effects, posing a risk to the sustainability of purple-spotted bigeye resources. Calculations demonstrate that the average fishing effort of bag net fishermen in Tegalsari Coastal Fishing Port is 1,294 trips, surpassing the MSY fishing effort of 1,041 trips. This indicates that fishery resources in the waters of FMA 712 are experiencing biological overexploitation. As noted by Widayanto et al (2021), overfishing conditions are observed in the Java Sea due to factors such as the growing number of fishermen and the utilization of environmentally unfriendly fishing gear.

MEY represents the optimal level of utilization or exploitation of purple-spotted bigeye resources by maximizing profitability. MEY calculations consider fishing effort and catch, aiming to achieve the highest profit among the approaches in the Gordon-Schaefer model. Research findings indicate that at the point of MEY, the catch (C_{MEY}) is smaller than the MSY catch (C_{MSY}), specifically 4,943,170 kg year^{-1}. The fishing effort required at MEY conditions (E_{MEY}) is 904 trips. At this point, the profit exceeds that of MSY and OAE, amounting to IDR 44,915,090,819. This signifies that the profit of IDR 44,915,090,819 represents the highest profitability achievable from purple-spotted bigeye fishing at Tegalsari Coastal Fishing Port. The MEY condition is primarily influenced by fishing effort, which impacts catch levels, thereby maximizing economic benefits. According to Dafiq et al (2019), the MEY condition represents a superior economic state, characterized by lower fishing effort and expenditure costs (TC), yet yielding higher economic returns compared to MSY and OAE conditions.

OAE represents the level of exploitation or utilization of purple-spotted bigeye resources under open access conditions, where neither profit nor loss occurs. OAE calculations involve a relationship between effort and catch and occur in the absence of government intervention or structured management. Research findings indicate that the catch at OAE is 2,304,830 kg year^{-1}, with a corresponding fishing effort of 1,808 trips year^{-1}. In OAE conditions, revenue equals expenditure, resulting in neither profit nor loss. However, this open-access scenario often leads to over-exploitation and inefficient resource use due to the absence of government intervention in management. As noted by Wijayanto et al (2016), the occurrence of OAE is characteristic of water resources that are publicly owned, resulting in the utilization of fish resources at a break-even point where revenue (TR) equals total cost (TC) incurred.

Based on the research findings, the utilization level of purple-spotted bigeye in Tegalsari Coastal Fishing Port, as per the Gordon Schaefer model, is heavily influenced by the catch, particularly concerning MSY and the actual catch. If the actual catch surpasses the MSY catch, it signifies overfishing in the resource production area. The highest exploitation rate occurred in 2021, reaching 122%, while the lowest exploitation rate was recorded in 2017 at 20%. The average utilization rate over the six-year period stands at 58%. TAC calculations reveal that 80% of the potential MSY lies between 5,030,756 and 4,024,605 kg. Irhamsyah et al (2021) classify exploitation rates into four levels: low (0-33%), medium (33.3-66.6%), optimal (66.6-99.9%), and excess (overfishing) (> 100%).

Fishing effort adds pressure on fish resource stocks. When the actual fishing effort surpasses the catching effort, it indicates that these waters have experienced numerous fishing trips. The highest level of effort was recorded in 2017, reaching 205%, while the lowest occurred in 2018, at 21%. The average effort level over six years stands at 124%. Juniko et al (2018) assert that the level of effort is influenced by the number of vessels per year; higher vessel numbers correspond to increased effort levels. This trend persists because fishermen continue to escalate their fishing efforts each year.

The internal and external factors were assessed through the analysis of interviews and questionnaires conducted with key stakeholders. Their responses will be quantified into scores, which will then determine the quadrant placement of the purple-spotted bigeye resource management strategy at Tegalsari Coastal Fishing Port. Assign weights to each response based on its alignment with internal or external factors. Calculate the rating for each response, considering that positive factors are rated +4 for significant opportunities and +1 for minor ones, and vice versa for negative factors.

Based on the assessment of internal and external factors, the analysis indicates that the factor with the strongest positive impact is S1, scoring 0.45, highlighting the availability of fish auction as a provider of marine catches, including purple-spotted bigeye. Conversely, the factor with the highest negative impact is W1, scoring 0.21, pointing to suboptimal fleet monitoring and the absence of legal sanctions for ship owners.

Regarding opportunities, the highest scoring factors are O1 and O4, both with a score of 0.46. O1 reflects the potential for optimizing purple-spotted bigeye production, which has shown fluctuations over the past 5 years, averaging 2,935,162 tons. O4 underscores the availability of market outlets and fish processing facilities around the port, covering an area of 784 m^2. For threats, the highest scoring factor is T3, with a score of 0.19, indicating the risk of common tragedy occurrence due to exceeding production levels, reaching 5,030,756 kg $year^{-1}$, and making 1,041 trips. The resource management strategy for purple-spotted bigeye at Tegalsari Coastal Fishing Port falls into quadrant I, signifying a Strength-Opportunity orientation, with coordinates (1.38; 1.25) on the X and Y axes respectively.

The utilization of purple-spotted bigeye resources suggests an occurrence of overfishing, attributed to the intense fishing activity. Hence, a fishery management policy that sets forth regulations governing the usage of fishing gear and delineates guidelines for the exploitation of purple-spotted bigeye should be implemented by encompassing optimal levels of effort and maximum catch yields, drawing from both biological and fish bioeconomic analysis approaches. Leveraging insights from the SWOT analysis, the following policy recommendations emerge:

- the regional government in cooperation with the central government to increase supervision and equip monitoring facilities and infrastructure in optimizing the potential of purple-spotted bigeye accompanied by appropriate regulations to prevent the occurrence of overfishing to produce biologically and economically sustainable catches;
- utilize experienced human resources supported by adequate facilities and optimize infrastructure in fishing activities by implementing central, regional and local government programs towards the development of supporting infrastructure for Tegalsari Coastal Fishing Port;
- to expand the fishing, marketing and processing networks by establishing cooperation between the government, investors and fishermen's associations to facilitate fishing business services.

Conclusions. The purple-spotted bigeye catch at Tegalsari Coastal Fishing Port has ben overfished, surpassing the sustainable threshold of 5,030,756 kg with a total of 1,041 fishing trips. The permissible catch stands at 2,935,162 kg, with an average exploitation rate of 58% and an effort level of 124%. The resource management strategy employed for purple-spotted bigeye in Tegalsari Coastal Fishing Port aligns with Quadrant I (SO strategy) as the primary approach, encompassing: (a) avoiding overfishing of purple-spotted bigeye, (b) enhancing the development of supporting infrastructure for Tegalsari Coastal Fishing Port and (c) optimizing the development of supporting infrastructure for Tegalsari Coastal Fishing Port.

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