Analysis of purple-spotted bigeye fish resource utilization landed at Tegalsari Coastal Fishing Port (CFP), Tegal City, Central Java

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Abstract. Purple-spotted bigeye (*Priacanthus tayenus*) is one of the demersal fish species with important economic value in Tegal. They are commonly caught using purse seine nets with 2 inches of mesh. This study aims to analyze the growth aspect and ecological sustainability of purple-spotted bigeye fish landed at Tegalsari Fishing Port. The research method used was a descriptive method. Data collection was conducted through a survey with a purposive sampling technique. The collected data included primary data (total length of the fish (mm) and fish weight (grams)) and secondary data (production quantity and number of fishing trips from 2017 to 2021). Data analysis was carried out using the ELEFAN 1 method using FISAT II software version 1.2.2 through Schaefer model analysis. The results of the research indicated that the purple-spotted bigeye landed at Tegalsari Fishing Port had a total length of 130-294 mm and a weight of 40-226 grams, in which the growth was categorized as negative allometric, where W = 0.00097L2.184. The growth of purple-spotted bigeye was formulated by the equation Lt = 269.98[1 – e1.40(t + 0.0612)]. The fish were considered suitable for capture and have reached gonadal maturation. The fishing mortality rate (1.56) was higher than the natural mortality rate (1.23), resulting in an exploitation rate (0.56) that indicated overfishing. The peak recruitment occurs from June to October. The sustainable yield of the fish was estimated at 5,275.337 kg year^{-1} with an optimum fishing effort of 1,041 trips year^{-1}. The average utilization and fishing effort rates for purple-spotted bigeye fish landed at Tegalsari coastal fishing port were 102.17% and 133.75% respectively.

Key Words: biological aspects, ecological sustainability, management, purple-spotted bigeye fish, Tegal city.

Introduction. Purple spotted bigeye fish (*Priacanthus tayenus*) is classified as the second most abundant demersal fish caught in Tegalsari CFP, which was 10.03% of the catch, followed by the kurisi fish (*Nemipterus* sp.) with 10.65% in 2021 (CFP Tegalsari 2022). The fish inhabits rocky areas at depths from 20 to 200 meters (www.fishbase.org). Generally, the fish are medium-sized, around 25-35 cm standard length (ST). They have large eyes (about half the length of their head), reddish with white or silvery spots, and dark blackish spots on their pelvic fins. The capture of the fish is primarily carried out using purse seine nets, which are the most fishing gear used in Tegalsari CFP, 61.02% in 2021 (CFP Tegalsari 2022).

Tegalsari CFP is a Type C fishing port based in Tegal City. Tegal City directly faces the North Java Sea and is still part of the Indonesian Fisheries Management Area (WPPNRI) 712. The utilization rate of demersal fishery resources in WPPNRI 712 is 110% (over-exploited). The allowable catch of demersal fish in WPPNRI 712 is 50% of its potential sustainable yield (Decree of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia No. 19 of 2022). This causes controversy due to the abundance of demersal fish resources in WPPNRI 712, such as red snapper (*Lutjanus* sp.), ponyfish (*Leiognathus* sp.), groupers (*Epinephelus* sp.), threadfin bream (*Nemipterus* sp.), goatfish (*Upeneus* sp.), purple-spotted bigeye (*Priacanthus* sp.), and many other demersal fish species that experienced overexploitation.

This study aims to determine whether the purple-spotted bigeye fish, a demersal fish species commonly caught in WPPNRI 712, is classified as overfished or not based on biological and ecological sustainability aspects. If the purple-spotted bigeye fish is experiencing overfishing, appropriate management measures are required to ensure the sustainability of its population.

Material and Method

Description of the study sites. This research was conducted in Tegalsari CFP, Tegal City, Central Java, the number of samples was 675 purple-spotted bigeye landed at Tegalsari CFP. The fishing grounds of purple-spotted bigeye fish included the southern waters of Kalimantan, specifically the waters of Tanjung Puting and Tanjung Selatan in Figure 1.

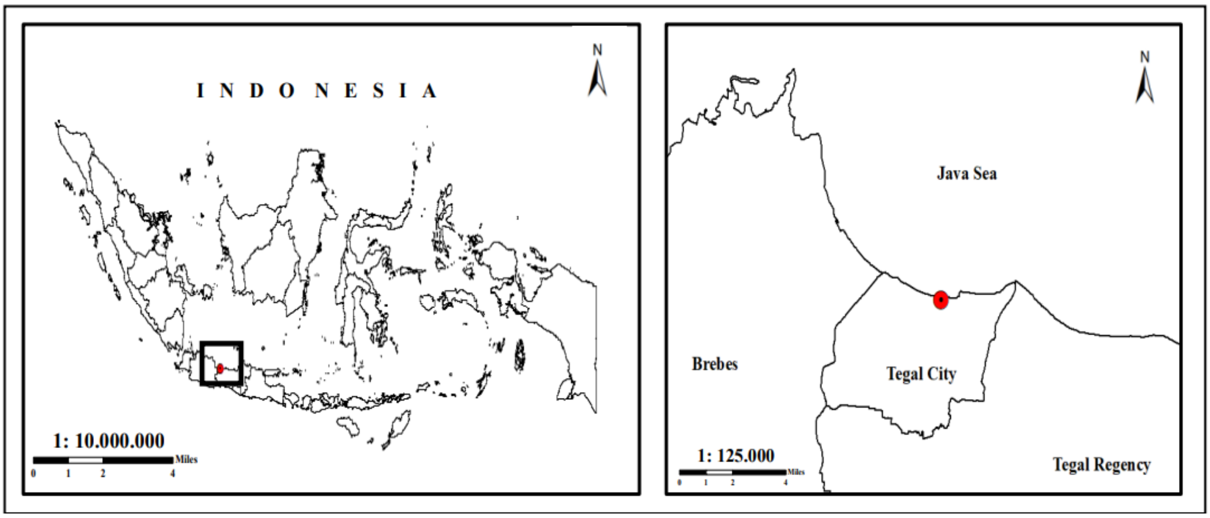

Figure 1. Research locations at Tegalsari CFP, Tegal city, Central Java, Indonesia.

Research methods. The method used in this study was a survey-based descriptive method. The data used in this research consisted of primary data and secondary data. Primary data were obtained by directly measuring the total length and weight of the fish at the research site through observation and surveys on 7 fishing vessels that landed fish at Tegalsari CFP. Secondary data were obtained from the Tegalsari CFP institution. The data taken were the number of catches and fishing effort.

Data analysis

Size structure. Fish size structure analysis was carried out as follows:
1. Determination of the class range (J) with the formula:
   J = the highest total length - the smallest total length
2. Determination of the number of class intervals using the equation:
   $K = 1 + 3.3 \log N$
3. Determination of the length of the class interval (C) using the equation:
   $C = J/K$

Length-weight relationship. Length-weight relationship analysis based on Effendi (1997) can be determined by the following equation:

$$W = a \times L^b \quad (1)$$

where: W = weight of fish (g);
L = length of fish (mm);
a = intercept;
b = slope.

Growth parameters. Estimation of growth parameters can be calculated using the ELEFAN 1 method with FISAT II and formulated by the Von Bertalanffy equation as follows:

$$L_t = L_\infty (1 - e^{-K(t-t_0)}) \quad (2)$$

where: Lt = length of fish at the age of t years (mm);
L∞ = asymptotic length of fish (mm);
K = coefficient of growth rate (mm year^{-1})
t = age of fish (years);
t_0 = measure the fish when it is 0 mm long (year).

The L∞ and K values were obtained using the ELEFAN 1 program on FiSAT II and the t0 values were obtained using the Gulland (1983) equation as follows:

$$\text{Log}(-t_0) = 0.3922 - 0.2752\ (\text{log}L_\infty) - 1.038\ (\text{log}_K) \quad \text{.............................. (3)}$$

Length at first capture (Lc). The size of the first time the fish was caught can be calculated by finding the value of the middle size of the fish caught. Determination of the size of the first caught fish can be done as follows:
1. creating a fish length class and calculate the frequency of each length class;
2. calculating the percentage frequency of each length class;
3. calculating the cumulative percentage of the frequency of each long class;
4. the Lc value is obtained by plotting the cumulative frequency of fish caught with their total length.

Mortality rate and exploitation rate. Total mortality (Z) can be estimated by projecting the total production curve using the *intercept* (a) and Ln N/t with the age of the relator according to the Gulland (1983) formula as follows:

$$\text{Ln } N/t = a - Zt \quad \text{.. (4)}$$

where: N = total fish at time t;
t = the amount of time needed to grow one class in length;
a = curve of number of catches to length.

Estimation of mortality can be calculated using the following equation:

$$F = ZM \quad \text{.. (5)}$$

So the exploitation rate equation (E) is obtained as follows:

$$E = \frac{F}{Z} \quad \text{... (6)}$$

where: Z = total mortality rate;
M = natural mortality rate;
F = mortality rate due to capture;
E = exploitation rate.

Pattern. Recruitment patterns are used to reconstruct recruitment pulses from time to time series using total length frequency data in estimating the number of recruitments per unit time and the total percentage of these recruitments. The parameters needed to calculate the recruitment pattern are L∞, K, and t0. The analysis was carried out with the help of the *Assess Menu* and *the Recruitment Pattern subprogram* in FISAT II.

CPUE (catch per unit effort). CPUE can be calculated using the following equation:

$$CPUE = \frac{\text{Catch}}{\text{Effort}} \quad \text{... (8)}$$

where: CPUE = catch per unit effort year i;
catch = number of production in year i;
Effort = number of fishing attempts in year i.

MSY (maximum sustainable yield). The sustainable potential of swanggi fish is estimated by analyzing catch and effort. The relationship between catch and fishing effort can use the Schaefer model production surplus method which is formulated as follows:

$$y = a - bx \quad \text{... (9)}$$

where: y = dependent variable (CPUE);
x = free variable (effort);
a = intercept;
b = slope.

Furthermore, the values of a and b are used to calculate the value of the optimum fishing effort and the amount of sustainable potential as follows:
- optimum fishing effort value: EMSY = (a/2b);
- sustainable potential value: CMSY = (a^2/4b).

Total allowable catch (TAC). The number of allowable demersal fish catches is differentiated based on WPPPNRI. The amount of fish catch allowed in WPPNRI 712 for demersal fish is 50% of the sustainable potential value. The calculation uses the following formula:

$$TAC = 50\% \times MSY \quad \text{.......} \quad (10)$$

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

Level of utilization and level of effort. The level of utilization and level of exploitation of fish resources can be formulated as follows:

$$\text{Utilization rate} = \frac{\text{Production}}{\text{TAC}} \times 100 \quad \text{.......} \quad (11)$$

$$\text{Effort rate} = \frac{\text{EFFORT}}{\text{EMSY}} \times 100 \quad \text{.......} \quad (12)$$

According to the Decree of the Minister of Maritime Affairs and Fisheries of the Republic of Indonesia Number 19 of 2022, the utilization level of demersal fish was categorized into three:
1. when the fishing effort carried out per unit of time exceeds the estimated sustainable yield (higher than 100%), it is classified as "over-exploited";
2. when the fishing effort carried out per unit of time is within 50%-100% of the estimated sustainable yield, it is classified as "fully exploited";
3. when the fishing effort carried out per unit of time is below 50% of the estimated sustainable yield, it is classified as "moderate".

Results and Discussion

Size structure. The number of samples used to measure the total length and body weight of purple-spotted bigeye fish was 675 fish with a size range of total length ranging from 130-294 mm and body weight ranging from 40-226 grams. The histogram in Figure 2 showed that the most landed fish in Tegalsari CFP had a total length of 190-204 mm for 197 individuals, while the least landed fish in Tegalsari CFP had a total length of 280-294 mm for 4 individuals.

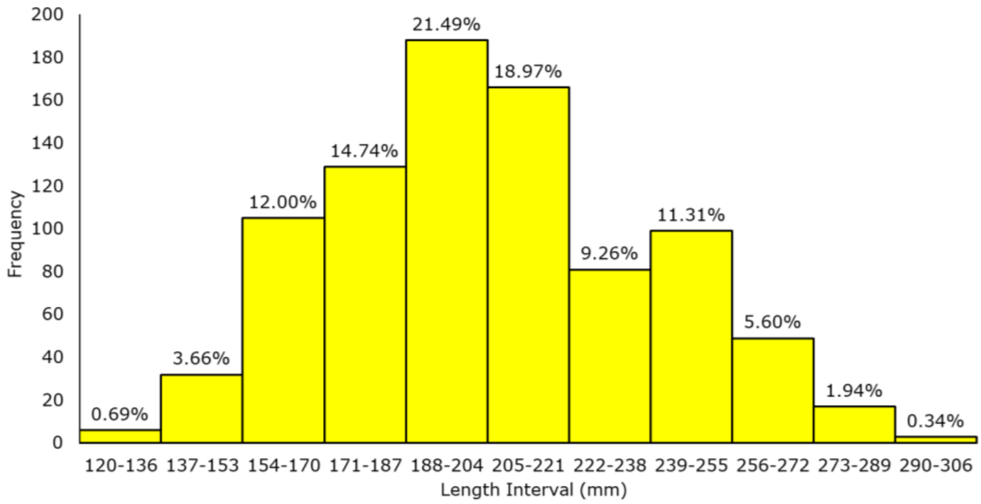

Figure 2. Size structure of purple-spotted bigeye fish histogram.

Length-weight relationship. The measurement of length-weight relationship using linear regression analysis with a 95% confidence interval obtained an intercept (a) of

0.00097 and a slope (b) of 2.184. Thus, the equation for the length-weight relationship was $W = 0.00097L^{2.184}$. The results of the length-weight relationship analysis are presented in Figure 3.

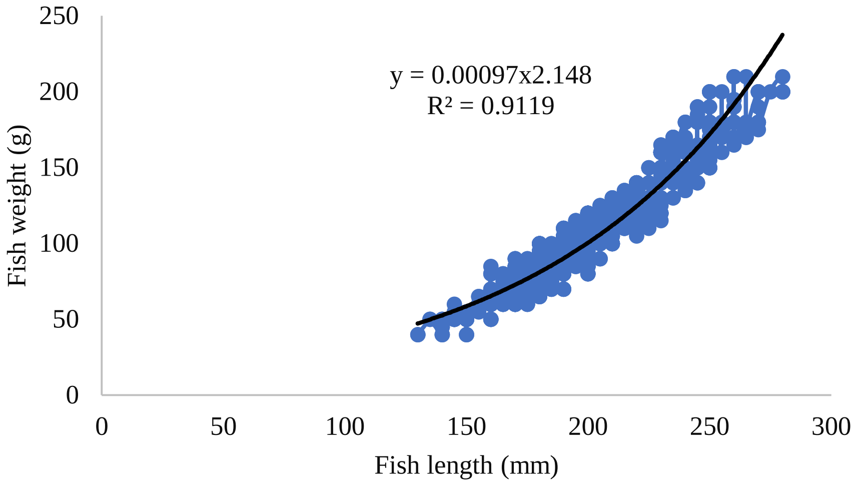

Figure 3. Length-weight relationship of purple-spotted bigeye fish.

The b value obtained illustrates that the growth of purple-spotted bigeye fish is in the negative allometric category (length growth is faster than weight growth) because the value is < 3. According to Sari et al (2021), the value of the coefficient b (*slope*) resulting from the length-weight regression can provide information on fish growth patterns. The value of b = 3 indicates an isometric growth pattern, b < 3 indicates a negative allometric growth pattern and b > 3 indicates a positive allometric growth. According to Supeni & Azizah (2020), differences in weight and length between fish can be influenced by various factors, where there are two factors that can affect fish growth, namely internal factors and external factors. The internal factors are difficult to control, while external factors are easy to control. Internal factors include heredity, sex, parasites and disease. While external factors are food, water quality, temperature, dissolved oxygen and carbon dioxide. According to Nugroho et al (2016), differences in the length-weight relationship of fish occur due to different environments with high levels of exploitation, thus changing the size structure of fish.

Growth parameters*.* Basically, growth involves the determination of the body size of a fish as a function of age (Sparre & Venema 1998). The results are shown in Figure 4 and indicated an asymptotic length ($L\infty$) value of 269.98 mm, a growth rate coefficient (K) of 1.40, and a t0 of -0.0612 years. The growth equation for purple-spotted bigeye fish was $Lt = 269.98[1 - e^{1.40(t + 0.0612)}]$.

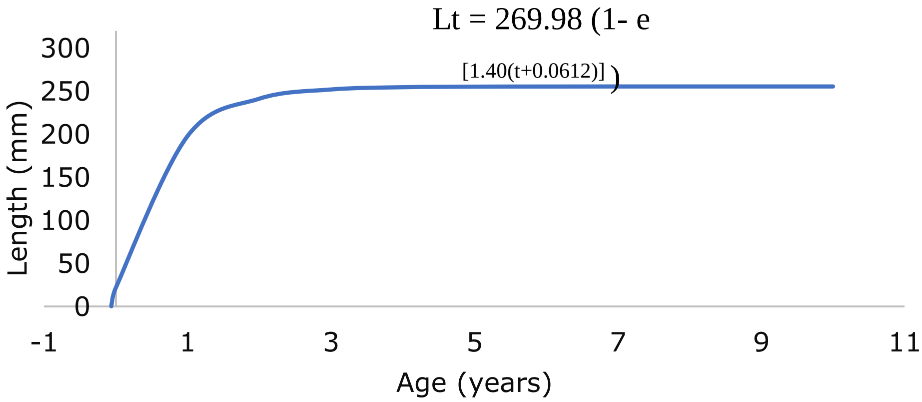

Figure 4. Von Bertalanffy growth chart of purple-spotted bigeye fish.

Growth is a parameter that shows length and weight in a certain period of time. Theoretically, the L∞ value indicates that the length growth of purple-spotted bigeye fish landed at CFP Tegalsari will stop at 255.43 mm in length, even though the fish age continues to increase. According to Faizah & Sadiyah (2019), the differences in growth parameter values of the same fish species at different locations are influenced by environmental factors such as food availability, water temperature, dissolved oxygen, and by internal factors like fish size and gonadal maturity.

***Length at first capture**.* The length value at first capture was measured to be used as a basis for setting the mesh size of the fishing gear and furthermore to ensure the sustainability of fish resources. The results of the length at first capture measurement are presented in Figure 5.

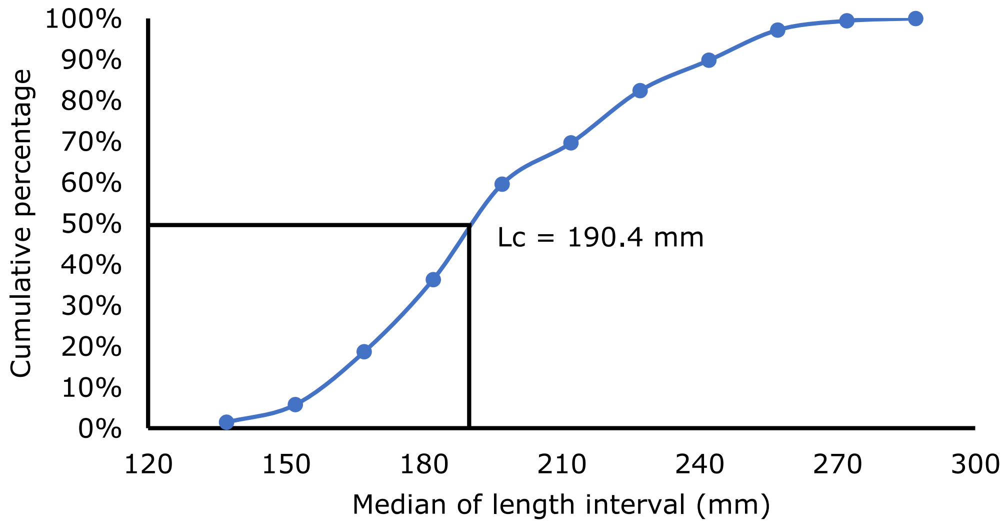

Figure 5. Length at first capture chart of purple-spotted bigeye fish.

The results showed that the length at first capture for the purple-spotted bigeye fish was 190.4 mm. The determination of a suitable size for capturing the purple-spotted bigeye fish was based on comparing the values of ½L∞ and Lc. The value of L∞ was obtained by dividing the maximum size of the purple-spotted bigeye fish by 0.95. The results of the data analysis showed that Lc (190.4 mm) > ½ L∞ (157.89 mm) for the purple-spotted bigeye fish landed in the Tegalsari CFP, so it can be concluded that the captured and landed purple-spotted bigeye fish is included in the category of fish that is appropriate for capture.

The size of the purple-spotted bigeye fish when it first matures can be used as a standard reference for the size of the catch. Ballerena (2012) found that the average size at first maturity of purple-spotted bigeye fish was 164 mm. In the present study, the Lc value was 190.4 mm. This condition is suitable for the sustainability of purple-spotted bigeye fish because before being caught the fish had already spawned (Prihatiningsih et al 2013).

Estimating the size of the first time a fish is caught aims to determine the mesh size of the net in the bag of fishing gear to maintain its sustainability (Agustiari et al 2018). Calculation of gear selectivity (SF) is done by dividing between Lc with the size of the mesh in the codend. The bag drag net used to catch purple-spotted bigeye in Tegalsari CFP has a mesh size of 2 inches (50.8 mm), so a SF value of 3.81 is obtained. According to Hufiadi et al (2014), the larger the size of the mesh in the net, the greater the chance for the fish to escape from the fishing gear.

***Mortality rate and exploitation rate**.* Mortality refers to the number of deaths within a population during a specific period. Mortality is generally divided into natural mortality (caused by age, predation, disease) and mortality caused by fishing activities. The values of mortality and exploitation rates are presented in Figure 6.

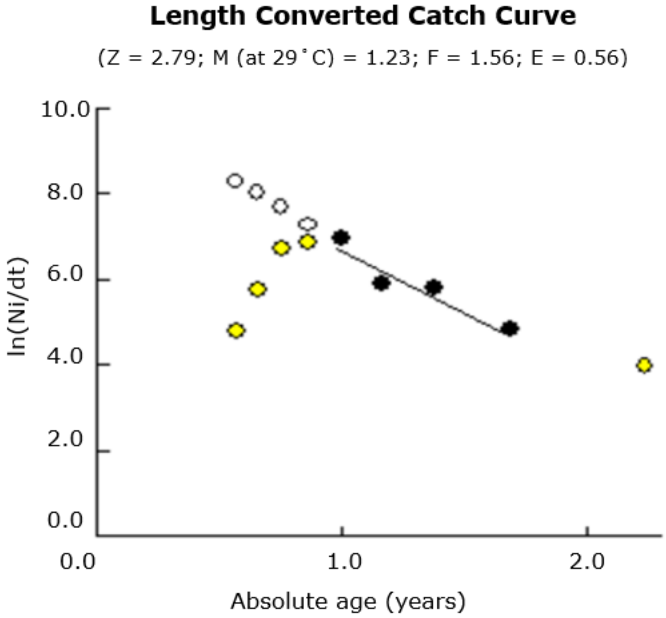

Figure 6. Mortality rate and exploitation rate of purple-spotted bigeye fish.

Based on the measurement results, it indicated that at an average water temperature of 29°C, the natural mortality rate (M) of purple-spotted bigeye fish was 1.23/year, the mortality rate due to fishing (F) was 1.56/year, and the total mortality rate (Z) was 2.79/year. The fishing mortality rate (F) was higher than the natural mortality rate (M). The exploitation rate of purple-spotted bigeye fish had a value of E = 0.56 (exceeding the optimum exploitation rate). If the value of E > 0.5 means that mortality due to fishing is greater than natural mortality (over-exploited). According to Gulland (1983), the fishing mortality rate is strongly influenced by the exploitation rate. The higher the exploitation rate, the higher the fishing mortality rate. The optimal exploitation rate is 0.50/year. According to Suman et al (2016), fish resources are seen as resources that can recover so that to ensure this, efforts are needed so that the rate of exploitation does not exceed the rate of recovery.

***Recruitment pattern**.* Recruitment refers to the entry of new individuals into their species group that occurs in nature during the spawning season. The approach used involved the utilization of growth parameter information such as L∞ (asymptotic length), K (growth coefficient), and t0 (age of the fish when the length is zero). The recruitment pattern of purple spotted bigeye fish landed in the Tegalsari CFP is presented in Figure 7. This measurement involved the estimation of the entire length frequency distribution data over a one-year time scale based on the Von Bertalanffy growth model. Based on the analysis using FISAT II, the recruitment pattern of purple-spotted bigeye fish in the North Java Sea occurs throughout the year. The spawning season is from April to August every year. The highest monthly percentage of purple-spotted bigeye fish recruitment occurs in June, with a percentage of 16.74%, while the lowest occurs in December with a percentage of 0%. This is supported by research conducted by Jabbar et al (2018), that recruitment of purple-spotted bigeye fish occurs in August-September and February-March. This is shown by the emergence of small fish in September which assumes they are approximately 1 month old. According to Rochman et al (2015), the recruitment pattern predicted by the FISAT program is still not in accordance with the reality in the field considering that the model is based on two assumptions that rarely occur in the field, where all fish samples grew with a single set growth parameter and in one month of the year there is always zero recruitment.

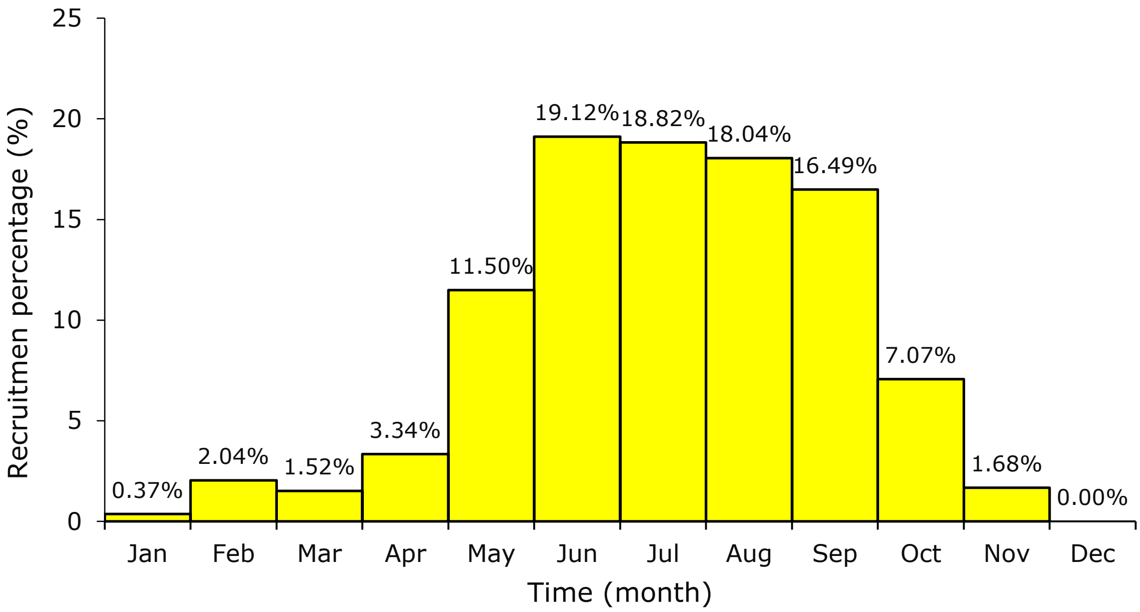

Figure 7. Recruitment patterns chart of purple-spotted bigeye fish.

CPUE (catch per unit effort). CPUE was obtained by dividing the total catch by the number of fishing efforts made within a specific period. The relationship between CPUE and the number of fishing efforts for purple-spotted bigeye fish is presented in Figure 8.

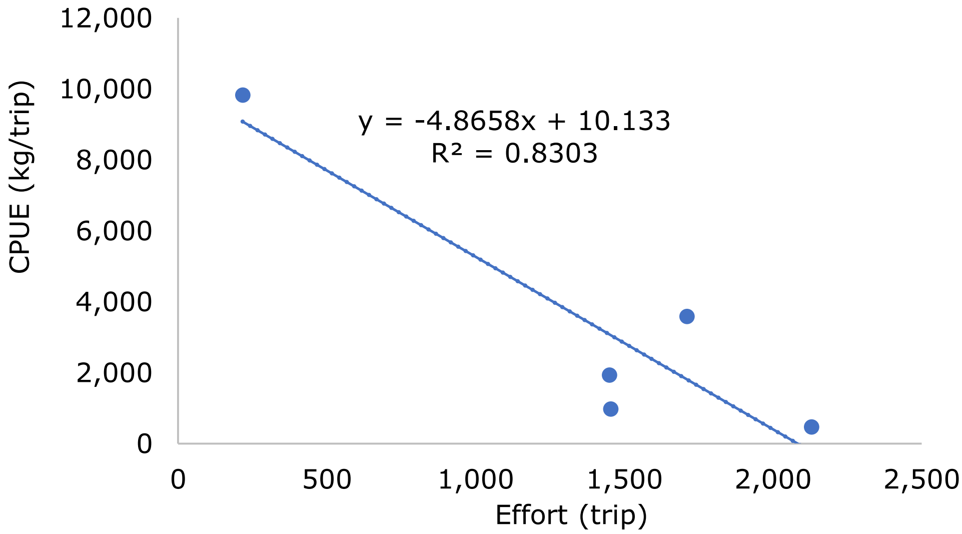

Figure 8. The relationship between CPUE and effort of purple-spotted bigeye fish.

Based on the linear regression analysis that has been carried out the relationship between CPUE and fishing effort on purple-spotted bigeye fish at Tegalsari CFP can be described by the equation $y = -4.8658x + 10.133$, with $R^2 = 0.8303$. This equation shows that the value of a (intercept) is 10.133 and the value of b (slope) is 4.8658. The correlation between CPUE and fishing effort has a negative relationship where the amount of production will not increase even if additional fishing effort is made. The fluctuations in CPUE values each year are influenced by the fluctuations in fishing effort made (Masrikat 2012). This negative correlation is due to the amount of production which tends to decrease if fishing efforts are carried out continuously (Estiyani et al 2022). According to Sari & Nurainun (2022), a decrease in the CPUE value indicates that potential fish resources are no longer able to produce more catches even though fishing efforts are increased.

MSY (maximum sustainable yield). The measurement of MSY is used to determine the maximum limit of a resource that can be harvested in the wild for economic purposes while ensuring the sustainability of the fisheries resource based on its natural conditions. The determination of MSY value used the surplus production approach with the Schaefer model. The data used for the MSY measurement were from the past 5 years (2017-2021) in the Tegalsari CFP, as shown in Figure 9.

The optimum fishing effort value was 1,041 trips year^{-1}, and the maximum production value was 5,275,337 kg year^{-1}. The measurement results indicated that in the Tegalsari CFP, there were excess trips in 2017, 2019, 2020, and 2021 (where the fishing effort per year exceeded the maximum fishing effort). The number of trips was below the maximum fishing effort value in 2018. Excess catches occurred in 2021 (where the production exceeded the maximum production value), while in 2017, 2018, 2019, and 2020, the production was below the maximum catch value.

The very low number of trips in 2018 was the result of the prohibition of the cantrang fishing gear through the Minister of Maritime Affairs and Fisheries Regulation Number 71 of 2016. Based on calculations, it was found that the average number of catches for five years was still below the sustainable potential value, while the average number of fishing efforts (for five years) has exceeded the limit of optimum fishing effort. According to Akoit & Nalle (2018), if the fishery potential is continuously exploited beyond the point of sustainable potential, there will be over-exploitation or utilization (over-fishing) resulting in a scarcity of fish resources. This scarcity will reduce production which results in low fishermen's acceptance and income so that it also impacts on economic losses or results in a loss of the economic chain.

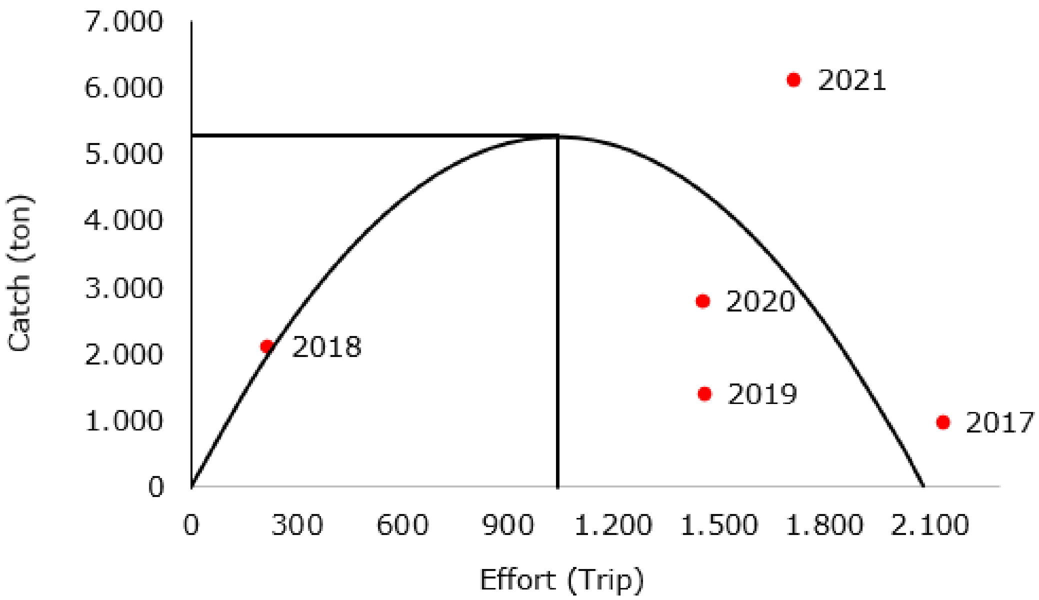

Figure 9. MSY Schaefer model of purple-spotted bigeye in Tegalsari CFP.

Total allowable catch (TAC). In order to ensure the sustainability of a resource, the allowed catch should be below the determined MSY value. The allowed catch is typically set at 50% of the maximum sustainable potential. Based on the measurement, the allowed catch for purple-spotted bigeye fish was 2,637,668 kg year^{-1}. The actual catch of purple-spotted bigeye fish in the past five years (2017-2021) was 2,637,668.43 kg year^{-1}. From 2017 to 2020, the production remained below the allowed catch, but in 2021, there was a difference where the production exceeded the allowed catch, which was 6,131,026 kg year^{-1}. Proper fisheries management involves the utilization of fish populations without depleting the resources entirely. Continuous fishing without considering the resource's capacity for renewal can be detrimental to fish stocks (Rahmawati et al 2013).

Utilization rate and fishing effort level. The utilization rate was measured based on the amount of fish utilized each year, while the fishing effort level was determined by the fishing efforts carried out. Achieving sustainable fisheries is important, and the categorization of utilization rates was assigned as follows according to the Decree of the Minister of Marine Affairs and Fisheries No. 19 of 2022:

a. moderate: if the utilization rate is below 50%;
b. fully exploited: if the utilization rate is between 50 and 100%;
c. over exploited: if the utilization rate exceeds 100%.

The utilization rate of purple-spotted bigeye fish resources in the Tegalsari CFP from 2017 to 2021 is presented in Figure 10. Based on the analysis, the condition of the purple-spotted bigeye fishery in the Tegalsari in 2017 experienced over-effort, but the catch was at a moderate level. In 2018, both the catch and trips were moderate. There was over-effort, but the catch was moderate in 2019. In 2020, there was over-effort, but the catch was still moderate. In 2021, there was both over-trip and over catch. According to a study by Wati et al (2014), indicators of overfishing in a fishery include catches exceeding the MSY, declining catch rates, and a decrease in the average size of caught fish. Since the purple-spotted bigeye fishery in the Tegalsari CFP has experienced overfishing, it is required to reduce fishing efforts to ensure the sustainability of the resource. According to Azkia et al (2015), one of the fisheries management aspects is stock assessment, which involves the estimation of the resource abundance. Stock assessment allows us to understand the level of resource utilization that has been carried out.

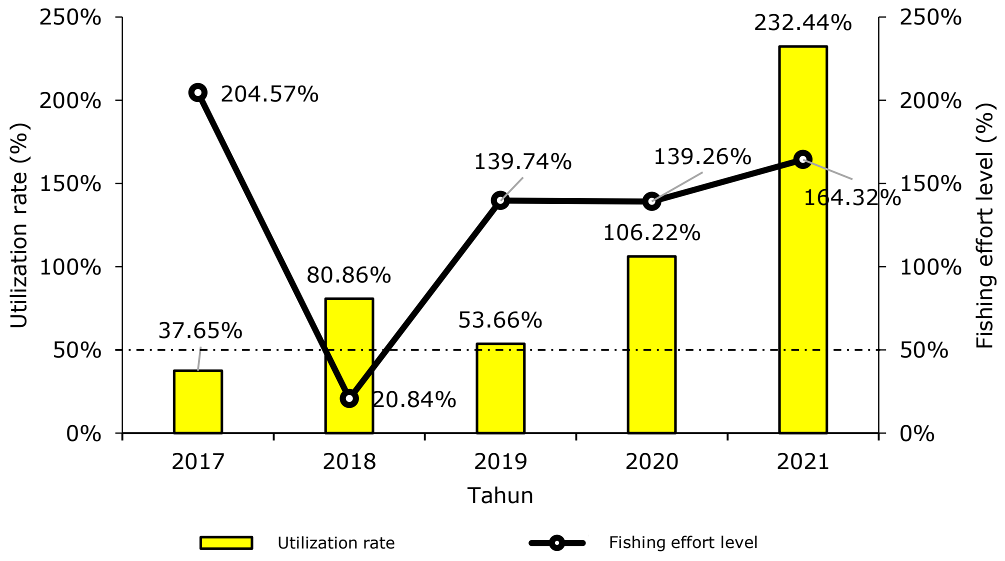

Figure 10. The histogram of the utilization and fishing effort rate of purple-spotted bigeye fish.

Management strategy. The results of the research indicated that purple-spotted bigeye fish caught in the Tegalsari CFP were suitable for fishing. However, the utilization rate and fishing efforts carried out were excessive. Management measures should focus on reducing the number of fishing vessels to reduce the catch and fishing effort. The use of purse seine nets with 2 inches of mesh in the pocket area should be maintained to prevent the capture of small fish and ensure the sustainability of the purple-spotted bigeye fish stock in the future.

Conclusions. Based on the analysis of the growth aspects of purple-spotted bigeye fish landed in the Tegalsari CFP, the following findings were obtained:

a. the size structure of the purple-spotted bigeye fish landed in the Tegalsari CFP was from 130 to 294 mm in length, and the weight was between 40 and 226 grams;

b. the growth of purple-spotted bigeye fish landed in the Tegalsari CFP showed negative allometric growth;
c. the Von Bertalanffy growth equation for purple-spotted bigeye fish landed in the Tegalsari FAD was $Lt = 269.98[1 - e^{1.40(t + 0.0612)}]$;
d. purple-spotted bigeye fish landed in the Tegalsari CFP were considered suitable for fishing because the value of Lc (190.4 mm) > ½ L∞ (157.89 mm), and they have reached gonadal maturation as Lc (190.4 mm) > Lm (164 mm);
e. the fishing mortality rate (1.56) was higher than the natural mortality rate (1.23), and the exploitation rate (0.56) indicated that the purple-spotted bigeye fishery was categorized as overfishing;
f. the recruitment pattern of purple-spotted bigeye fish occurs throughout the year, with peak recruitment observed from June to October.

The CPUE value tended to increase, with the highest CPUE occurring in 2018 due to low fishing activity. The sustainable yield production of purple-spotted bigeye fish was obtained at 5,275,337 kg year^{-1}, with an optimal fishing effort value of 1,041 trips year^{-1}. The average actual production has exceeded the total allowable catch.

The average utilization rate of purple-spotted bigeye fish from 2017 to 2021 was 102.17%, indicating overutilization. The average fishing effort rate for purple-spotted bigeye fish from 2017 to 2021 was 133.75%.

Conflict of interest. The authors declare that there is no conflict of interest.

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