Biological aspects and utilization of shortfin scad (*Decapterus macrosoma*) in the waters of Ternate, North Maluku, Indonesia

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Abstract. *Decapterus macrosoma* is an economically important type of small pelagic fish in the waters of Ternate Island, which is exploited by fishermen with various types of active fishing gear such as purse seine, chartreuse and gillnet. The Java Sea and surrounding waters are the largest producers in Indonesia, but stocks of this type are also experiencing saturation due to excessive fishing pressure. This research was carried out from February 20th to May 20th 2023 in the Ternate waters. The data collection during this research followed a survey method, namely by conducting direct *D. macrosoma* observations in the field. Primary data was collected by observing, measuring and dissecting fish captured using the random sampling method, while secondary periodic data (time series) on catch results and fishing effort over the last 5 to 10 years were gathered mainly from administrative sources. The aim of this research was to study biological and reproductive aspects, and fisheries aspects. The results of the research include the length of *D. macrosoma* that was the most caught, namely around 22 cm (as many as 552 fish) and the size of the specimens that were caught the least, namely around 34 cm (as many as 0 fish). The sex ratio for female fish was 56%, more than male fish (44%). Overall, the relationship between length and weight of female fish showed a negative allometric growth pattern, b<3 meaning that the weight increase was faster than the increase in length. The fishing seasons in the Ternate waters throughout the year are: the peak season from March or April to October, and the lean season from November to February, when fishermen do not go to sea. The high effort of catching *D. macrosoma* causes a reduction in the population abundance, resulting in catches decrease.

Key Words: gonad maturity level, sex ratio, gonad maturity index, MSY.

Introduction. Shortfin scad (*Decapterus macrosoma*) is distributed throughout the world, inhabiting tropical and subtropical waters in the Indo-Pacific and Atlantic Ocean (Liestiana et al 2015; Zhang et al 2020). The city of Ternate has a marine area reaching 73% of its total area, sheltering an abundant fishery resource potential (Sangaji et al 2016), and the number of catches in Ternate waters continues to increase year by year (Assagaf et al 2020). *Decapterus* sp. is an economically important type of small pelagic fish in the waters of Ternate Island which is exploited by fishermen with various types of active fishing gear such as purse seine, liftnet and gillnets (Tangke & Talib 2023).

D. macrosoma has a slender, elongated, slightly rounded body (Astuti et al 2021). Identification of this type of fish is carried out visually by looking at the color pattern and body shape and special characteristics, based on the guidelines for identifying small pelagic fish species (Hasrun & Kasmawati 2021). The abundance of fish in a body of water is influenced by oceanographic parameters (Semedi et al 2023; Kemhay et al 2019). The preservation of *D. macrosoma* resources in Ternate waters needs to be maintained, considering its quite large role in the fisheries sector (Asni et al 2019). Optimal and sustainable management needs to be carried out to maintain the species abundance and for the welfare of fishermen in Ternate waters (Faizah & Sadiyah 2019). The distribution area of *D. macrosoma* is wide and has been exploited intensively in various waters in Indonesia (Pattikawa et al 2017). The Java Sea and surrounding waters are the largest producers in Indonesia, but stocks of this type are also experiencing depletion due to an excessive fishing pressure (FAO 2013; Suwarso & Zamroni 2013).

Based on the above background, research on *D. macrosoma* in Ternate waters was carried out with the aim of 1) examining biological and reproductive aspects which include frequency distribution, length-weight relationship, sex ratio, gonad maturity level (GML), gonad maturity index, average length at first capture (Lc), average length at first maturity of gonads (Lm), and 2) examining fisheries aspects including: fishing vessels and fishing gear, fishing seasons, fishing ground, catch per unit of effort (CPUE), maximum sustainable yield (MSY), and utilization rate. It is hoped that the results of this research will provide important information for policy makers in fisheries management area in Ternate waters, North Maluku Province.

Material and Method. This research was carried out from February to May 2023, in Ternate waters with the sampling locations shown in Figure 1.

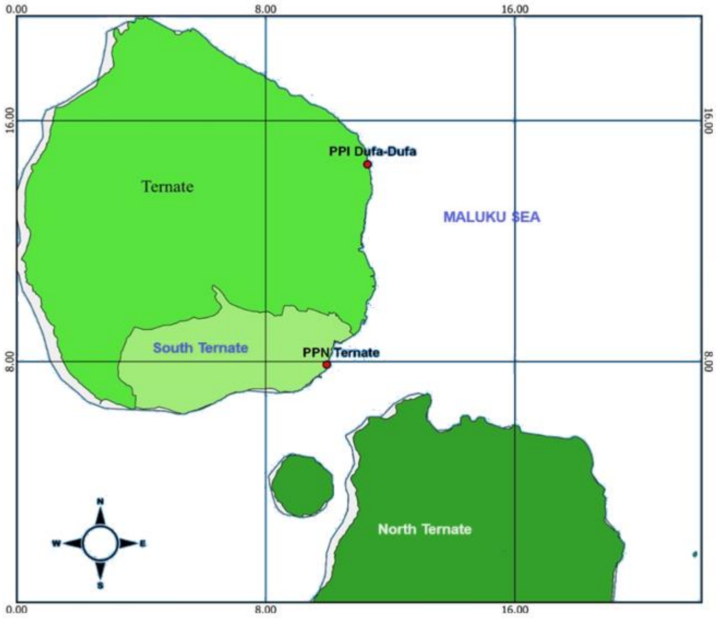

Figure 1. Research location map.

The tools used in carrying out this research include: meter, scales, camera, small knife, magnifying glass, questionnaire, stationery, and *D. macrosoma* specimens, as the object of this research.

Method of collecting data. The data collection method during this research used a survey method, namely by conducting direct observations in the field on *D. macrosoma*, which was the target of observation (Lokollo & Mailoa 2020). Primary data was collected by observing, measuring and dissecting *D. macrosoma* specimens selected using the random sampling method. Meanwhile, the secondary data required in the form of periodic data (time series) on catches and fishing efforts for the last 5 to 10 years were obtained from agencies as well as from other supporting data sources.

Data processing methods. Data processing includes tabulation and data sorting activities, in order to be presented qualitatively in the form of tables or graphs.

Data analysis method

Length frequency distribution. The length frequency distribution was obtained by determining the class interval, class mean value and frequency in each length group, then it was presented in a diagram.

Length-weight relationship. The length-weight relationship using the linear allometric model is used to calculate allometric parameters a and b through weight and length measurements. Length and weight analysis was carried out to determine the growth pattern of *D. macrosoma* using an exponential relationship model (Alnanda et al 2020). The analysis of the length-weight relationship used by Effendi (2002) can be expressed in the following equation (Azizi et al 2020):

$$W = aL^b$$

Where:
W - fish body weight (g);
L - fish body length (cm);
a and b - constant coefficients (population-specific);
a - intercept (intersection of the curve of the length-weight relationship with the y-axis);
b - slope.

Then it is transformed into a linear logarithmic equation, so that the form of the equation is (Hile 1936):

$$\text{Log W} = \text{Log a} + \text{b Log L}$$

Parameters a and b were obtained by regression analysis, with Log W as 'y' and Log L as 'x' (Muhsoni 2019):

$$Y = a + bx$$

In this analysis of weight length relationships, what needs to be considered is the value of b which can be interpreted as follows (Perangin-Angin et al 2015; Effendie 1997):
1. $b < 3$: Length gain is faster than weight gain (negative allometry)
2. $b = 3$: Length gain balanced with weight gain (isometric)
3. $b > 3$: Weight gain is faster than length gain (positive allometry)

The b value from the results of the analysis of the length-weight relationship illustrates the balance between length growth and weight growth in the fish body (Marasabessy 2020). If the b value = 3, then the growth is isometric and the fish body's shape and specific gravity do not change during the growth process. If the b value is not equal to three then the growth is allometric.

Gonad Maturity Level (GML). GML is determined morphologically by observing the shape, color and size of the fish gonads (Prianto et al 2021). The level of gonad maturity is divided into five stages, namely GML I (immature), GML II (maturing), GML III (mature), GML IV (fully mature), and GML V (resting) (Rachmanto et al 2018). The GML was determined in the gonads obtained from fish that have been dissected, by studying the gonad size and gonad morphology. The stages of fish gonad development are determined morphologically (Andriyono et al 2022).

Gonad Maturity Index (GMI). The GMI is calculated using the formula (Effendie 1997):

$$GMI = \frac{Wg}{W} \times 100$$

Where:
Wg - gonadal weight (g);
W - fish body weight (g);
GMI - gonadal maturity index.

Sex ratio analysis. According to Fisher (1930), the ratio of male to female individuals is estimated at 1:1 naturally in water with a normal spreading population. The equation used to calculate the sex ratio is as follows:

$$\text{Sex ratio} = \frac{nJ}{nB}$$

Where:
nJ - the number of male fish (individuals);
nB - the number of female fish (individuals).

Length at first mature gonads (Lm). Research on fish reproductive biology can provide important data and information regarding the spawning frequency, success rate and time, and the size of the fish when they first reached the gonadal maturity (Mardlijah & Patria 2016). Determining Lm can use the frequency distribution of the specimens that have matured gonads. The Lm was calculated using the Spearman-Karber equation (Islamiati et al 2018):

$$M = x_k + \frac{d}{2} - (d\sum Pi)$$

$$M = \text{antilog}\ (m \pm 1.96\ \sqrt{x^2 \Sigma \frac{pi*qi}{n_i - 1}})$$

Where:
m - logarithm of the length class at its first maturity;
d - logarithm of the increase in the median length;
k - number of length classes;
x_k - logarithm of the median length where the fish is 100% gonadal mature (or where p_i=1);
p_i - ratio of the mature fish in the length class i to the number of fish on the length interval i;
n_i - number of fish in the length class i;
q_i - 1 – p_i;
M - length of fish at first maturity equal to anti-log m, if $\propto$=0.05, then the confidence interval is 95% of m.

The Lm50 (the mean fish length at first sexual maturity; %) value is obtained by plotting the cumulative percentage proportion of gonad mature fish with each standard fish length. The Lm is calculated using the following formula (Zamroni et al 2019).

Length at first capture (Lc). The length of fish at their first capture (Lc) was estimated by the method (Sparre & Venema 1998):

$$SL = \frac{1}{a + \exp(a - bL)}$$

Where:
SL - estimated length value;
L - middle value of length (cm);
a - intercept;
b - slope.

The length at first capture (LC_{50}) is the length class at which the probability of being first captured is 50%, obtained by plotting the cumulative frequency curve of fish caught against its length curve (Diningrum et al 2019). Lc, which can be calculated through the formula:

$$Lc = a / b$$

Catch Per Unit Effort (CPUE). The CPUE calculation aims to determine the abundance and level of fish utilization based on the division between total catch and effort:

$$CPUE_i = Catch_i / Effort_i$$

Where:
$CPUE_i$ - catch per unit fishing effort in year i (tons/unit);
$Catch_i$ - catch in year i (tons);
$Effort_i$ - catching effort in year i (units).

Maximum Sustainable Yield (MSY). MSY can be estimated using the Schaefer model with data on catch and fishing effort over several years. MSY can be estimated using the formula (Sparre & Venema 1998):

$$MSY = \frac{Y}{f} = \frac{Y(i)}{f\ (i)}, \ i = 1, 2, \ldots n$$

Where:
$Y_{(i)}$ - catch in year i, i=1,2, ...n;
$f_{(i)}$ - catching effort in year i, i=1,2......n.

Determining the values of a (intercept) and b (slope) requires linear regression off$_{(i)}$ against $Y_{(i)}$. After the values a and b are obtained, the optimum effort (f_{MSY}) and maximum sustainable catch (MSY) can be calculated using the formula.

$$f_{MSY} = -\frac{a}{2b} \text{ and}$$

$$MSY = -\frac{a^2}{4b}$$

Furthermore, the level of utilization of fish resources was determined as the ratio of the number of catches in a certain year against the maximum sustainable production value (MSY), as follows (Tirtadanu et al 2018):

$$\text{Utilization rate} = \frac{Ci}{MSY} \times 100$$

Where:
C_i - current number of catches;
MSY - maximum sustainable yield.

Results and Discussion

Length frequency distribution. Based on the data gathered during the 3 months of observation of 1000 fish specimens, the number of females exceeded the number of males. The size distribution of fish varies based on gender. The size of male fish ranges from 20 to 21.7 cm. Meanwhile, female fish length ranges from 21 to 22.6 cm. The length distribution of the fish caught can be seen in Figure 2.

Figure 2 shows that among the *D. macrosoma* specimens observed in the study (1,000 fish), the size of 22 cm was dominant. The most frequently caught length was 22 cm (552 fish) and the least caught length was 34 cm (0 fish). These results are similar to the research conducted by Radongkir et al (2018), which stated that *D. macrosoma* had a Lm of around 22.4 to 22.6 mm.

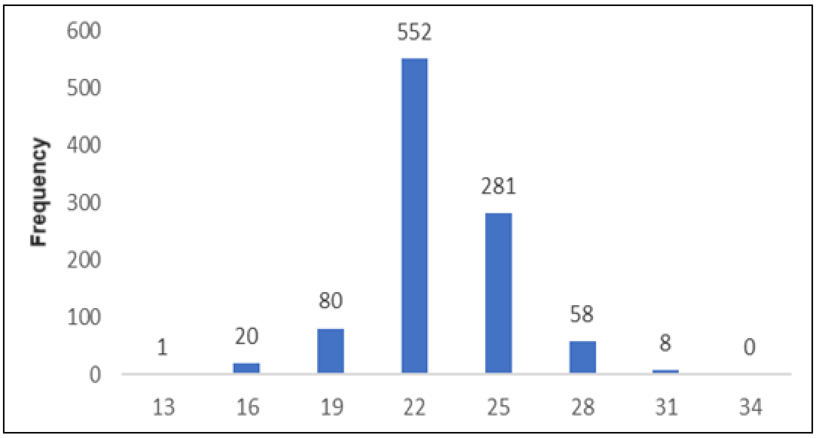

Figure 2. Length frequency of *Decapterus macrosoma* in Ternate waters.

Sex ratio. Among the total of 1,000 *D. macrosoma* samples observed in this research, 278 were dissected and the male to female sex ratio was determined. It was found that 122 (44%) specimens were male fish and 156 (56%) specimens were female fish (Figure 3).

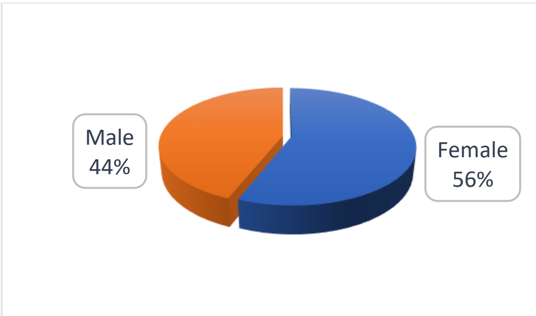

Figure 3. Sex ratio of *Decapterus macrosoma.*

The sex ratio of 1:0.80 indicates a dominance of females (56%), which means that the capture of male and female *D. macrosoma* is not balanced, because there is a deviation from the 1:1 pattern, which is the ideal condition for a population to maintain the species.

Length weight relationship. For 1,000 samples with a coefficient value of b=2.49612. The relationship between length and weight of *D. macrosoma* shows a negative allometric growth pattern (b<3), meaning that the weight increase is faster than the length increase. (Figure 4). The relationship between fish length and weight is presented in Table 1.

Table 1

The weight length relationship of *Decapterus macrosoma* captured

Fish samples	*$W = aL^b$*	*R^2*	*R*	*n*	*T-test*	*Growth characteristic*
D. macrosoma	$W = 0.058L^{2.4961}$	0.7699	0.8774	1000	37.19 > 1.96 ($T_{value} > T_{table}$)	Negative allometric

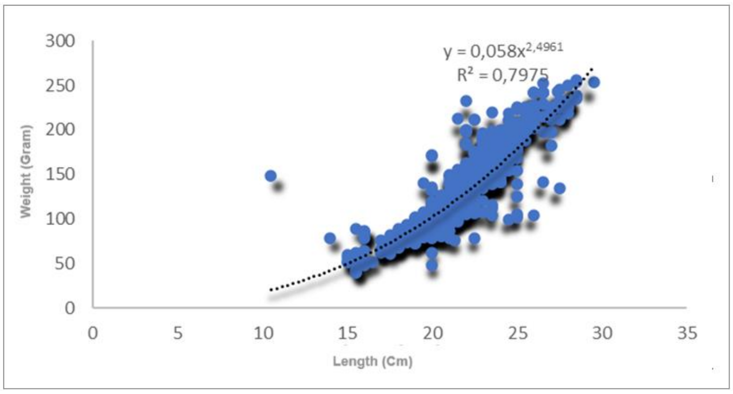

Figure 4. Relationship between length and weight of *Decapterus macrosoma*.

Gonad maturity level. Among the 278 *D. macrosoma* fish dissected, the gonad maturity level was successfully determined in all specimens, ranging from GML I to IV, as it can be seen in Figure 5.

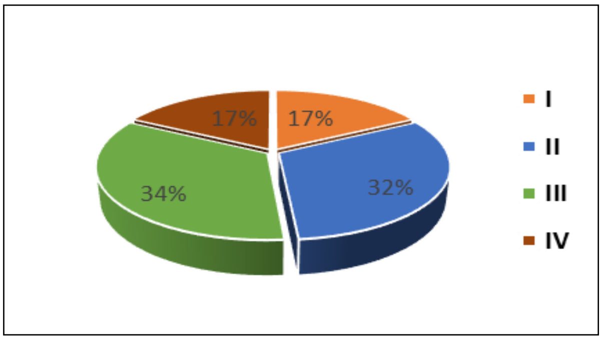

Figure 5. Total gonad maturity level of *Decapterus macrosoma.*

The above diagram shows that the GML (in male and female of *D. macrosoma* for which it was successfully identified) was classified as: GML I in 48 fish (17%), GML II in 87 fish (32%), GML III in 95 fish (34%) and GML IV in 48 fish (17%). The dominance of GML III indicates that most of the fish caught have reached the mature gonad level.

A GML breakdown by sex was performed. The diagram in Figure 6 shows the GML of *D. macrosoma* males caught in Ternate waters.

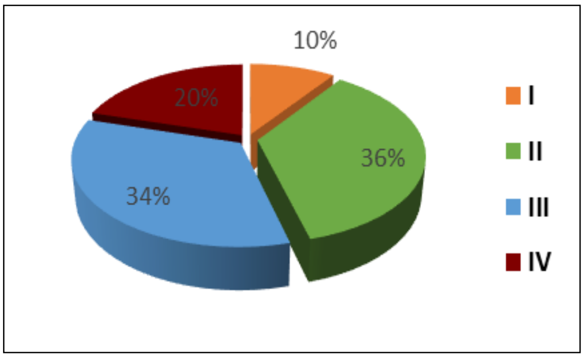

Figure 6. Gonad maturity level of *Decapterus macrosoma* males.

A total of 122 male *D. macrosoma* caught in Ternate waters were landed at 2 landing points, with GML I in 12 fish (10%), GML II in 44 fish (36%), and GML III in 41 fish (34%) and GML IV in 25 fish (20%). Thus, it can be concluded that the GML II dominates in the male fish. They are in the stage of gonad maturation but have been caught before the maturity completion.

The diagram in Figure 7 shows the GML of *D. macrosoma* females:

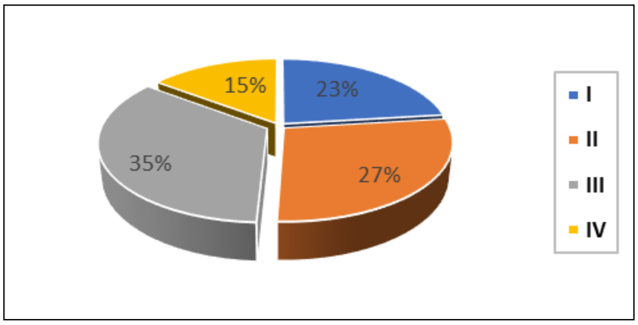

Figure 7. Gonad maturity level of *Decapterus macrosoma* females.

A total of 156 female *D. macrosoma* caught in Ternate waters were landed at 2 landing points, with GML I in 36 fish (23%), GML II in 43 fish (27%), GML III in 54 fish (35%) and GML IV in 23 fish (15%). GML III dominates in the female fish. They reached the stage of gonad maturity but have been caught before reproduction.

Gonad Maturity Index (GMI). The GMI of male and female *D. macrosoma* showed variations, where the lowest fish GMI ranged from 2.15%, while the highest of GMI ranged from 2.22%, as seen in Figure 8 below.

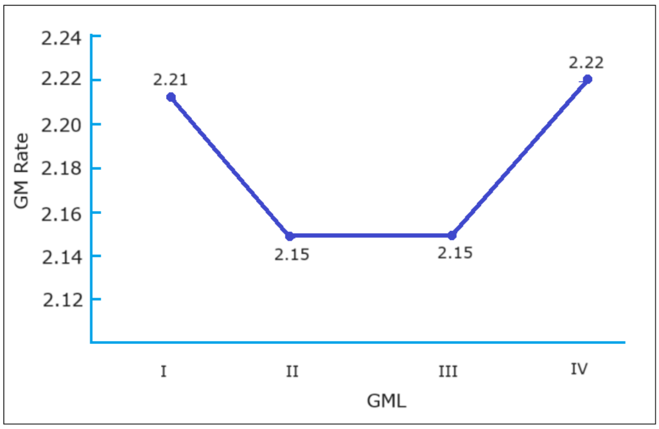

Figure 8. The gonad maturity index of *Decapterus macrosoma.*

Based on the diagram above, it is found that the average GMI value for males and females of *D. macrosoma* ranges from GML I, namely 2.21, GML II 2.15, GML III 2.15, and GML IV 2.22.

Length at first capture (Lc). Biological indicators in the context of assessing the abundance of *D. macrosoma* resources are observed based on the comparison between Lc values. Among the 1000 fish caught, the average length at the first capture was 23.08 cm, as seen in Figure 9.

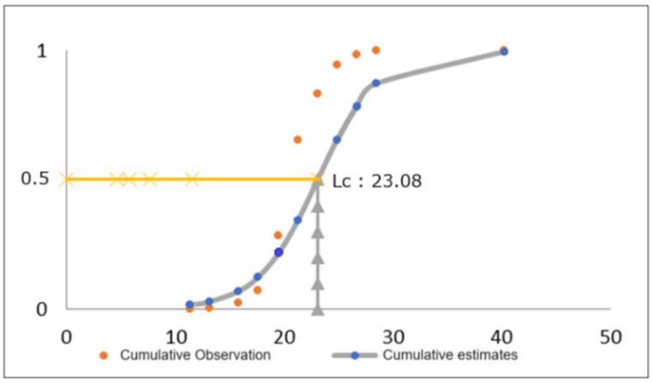

Figure 9. Length at first capture of *Decapterus macrosoma.*

Lc calculations were carried out using the cumulative frequency of each length class of fish caught by the purse seine.

Length at first maturity (Lm). Biological indicators in the context of assessing the abundance of fish resources are seen based on the comparison between Lm (Figure 10).

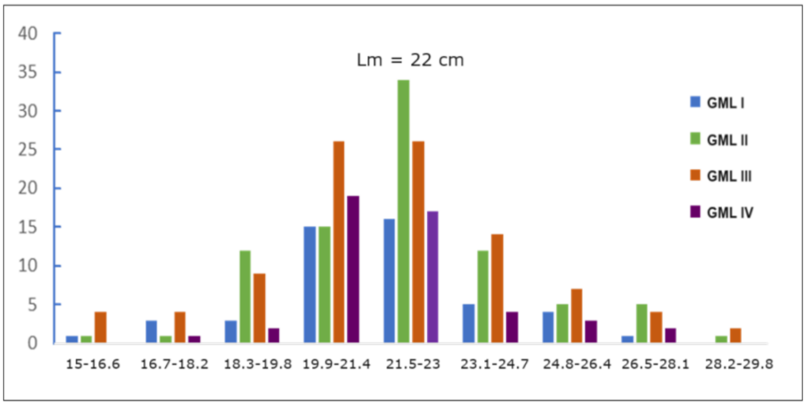

Figure 10. Length at first maturity gonads of *Decapterus macrosoma*.

From the results of observations that have been made on the GML length distribution of 278 *D. macrosoma*, it is estimated that the length at first maturity of the gonad is Lm 22 cm, with a size range from 21.5 to 23 cm. Based on the analysis data, it was found that the Lc value was greater than Lm.

Fishing vessels and equipment. Purse seine vessels operating in Ternate waters are generally made of wood with an average size of 16 to 30 GT. The machines used have an average power of 120 HP. Catching *D. macrosoma* generally uses purse seine fishing gear, with an average crew size of 13 to 20 people.

Fishing season. The fishing season in Ternate waters is throughout the year, January, March, April to October is the peak season and February, November and December are the low season. From January to October there is a west wind in the North Maluku Sea; the wind is blocked by the islands so it has no effect on the state of sea waves. The fishing season graph can be seen in Figure 11 below:

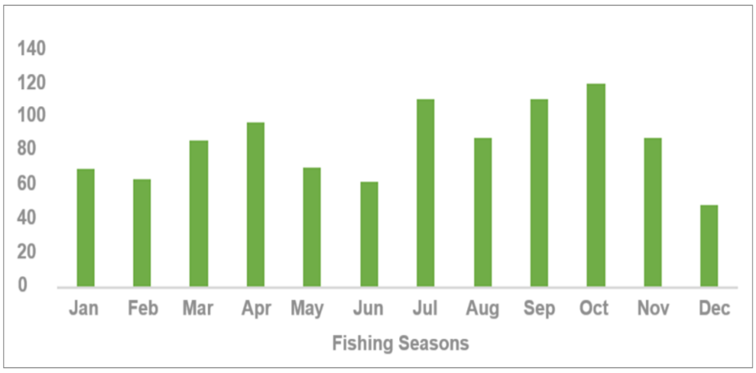

Figure 11. Fishing seasons of *Decapterus macrosoma* from January to December.

Fishing areas. Based on the results of interviews with fishermen in Ternate, the fishing area is as shown in Figure 12 below:

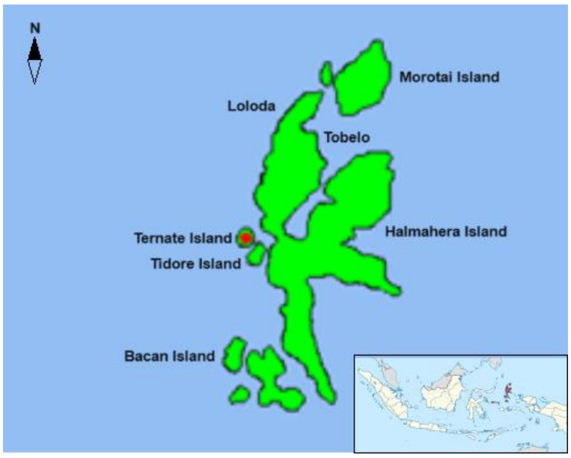

Figure 12. Location of catching *Decapterus macrosoma*.

Locations for catching *D. macrosoma* in Ternate waters include Morotai Island, Tidore Island, Bacan Island, Loloda, Tobelo, and Halmahera Island which are fishing grounds for *D. macrosoma* and other pelagic fish.

Catch Per Unit Effort (CPUE). Based on the results of interviews with fishermen, *D. macrosoma* was caught using purse seines, which is the most dominant fishing gear used in Ternate. Table 2 below explains the production value/trip of *D. macrosoma* in Ternate waters.

Table 2

Production/trip value of *Decapterus macrosoma* in Ternate waters

Year	*Production (Ton)*	*Effort (Trip)*	*CPUE*
2018	1,787	778	2.2973
2019	1,570	841	1.8672
2020	1,272	514	2.4752
2021	396	293	1.3508
2022	408	305	1.3387

D. macrosoma production in 2018 was 1,787 tons a year, experiencing a decrease in 2019 with total production of 1,570 tons a year and decreased in 2020 with total production of 1,272 tons a year. Then it decreased in 2021 with total production of 396 tons a year and in 2022 there was an increase in production again to 408 tons a year. The following is the relationship between *D. macrosoma* production and fishing effort recorded from 2018 - 2022 in Ternate Waters, North Maluku (Figure 13).

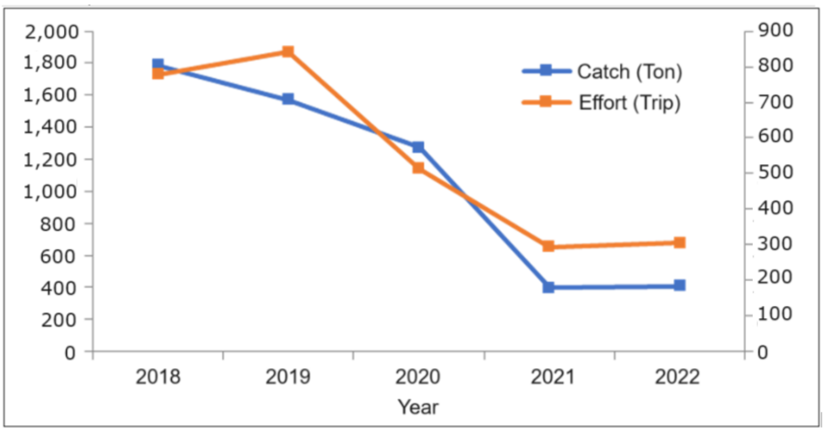

Figure 13. Development of catch production, effort and CPUE.

Based on the CPUE value, it fluctuated from 2018 to 2022. The highest production value was in 2018, namely 1,787 tons a trip and the lowest in 2022, namely 408 tons a trip. Meanwhile, the value of efforts a trips fluctuates from 2018 to 2022. With the highest value of 841 in 2018 and the lowest value in 2022 with a value of 305 attempts a trip. The CPU fluctuation value can be seen in Figure 14.

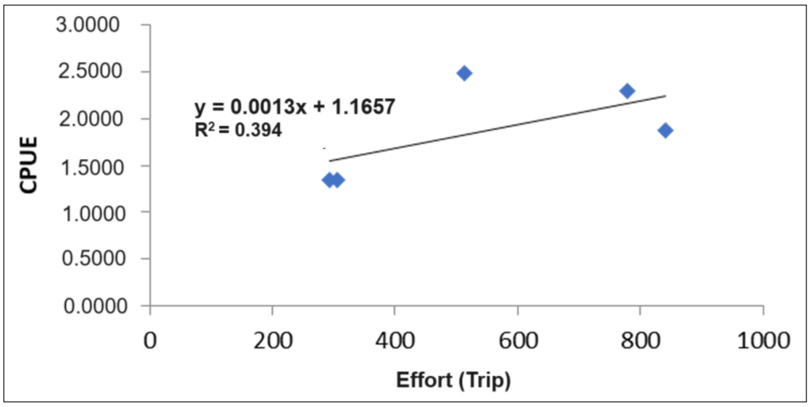

Figure 14. The relationship between CPUE and effort in a linear equation.

Based on the results of the analysis of the relationship between catch effort (trip) and CPUE, the intercept (a) = 1.1657 and slope (b) = 0.0013x were obtained, thus forming a linear equation y = 0.0013x + 3.4697 which indicates a positive relationship between production and effort that every increase in 1 trip will cause CPUE to increase by 0.0013 tons per trip. The coefficient of determination (R^2) is 0.394 (or 39.4%), suggesting a weak relationship between the two variables: 39.4% of the CPUE variability is explained by the effort, while the remaining variability is influenced by other factors which are not mentioned, such as the amount of motor fuel used, ship size, engine power, lamp power, and others.

Maximum Sustainable Yield (MSY). Based on *D. macrosoma* production data in the 2018 to 2022 period, MSY can be calculated using Schaefer's production surplus method. The sustainable potential value and optimum effort of *D. macrosoma* can be determined during the research so that overfishing can be determined by comparing the effort and catch each year. The data used in MSY calculations are *D. macrosoma* production data and per-trip data (Figure 15).

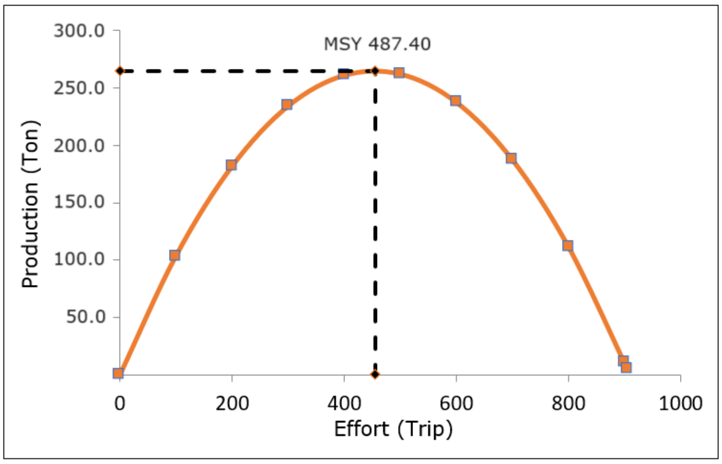

Figure 15. *Decapterus macrosoma* fisheries conditions compared with stock balance model.

Based on the Schaefer model, the optimum fishing effort value was found to be 454.7197 trips a year and the maximum sustainable catch value was 265.0342 ton year^{-1}. During the period 2018-2022, the yearly catches exceeded the MSY value.

Maximum Sustainable Yield (MSY). The utilization rate is calculated by the ratio of the total catch in a particular year against the MSY value for the same period. The level of utilization of *D. macrosoma* in Ternate waters can be seen in the Figure 16.

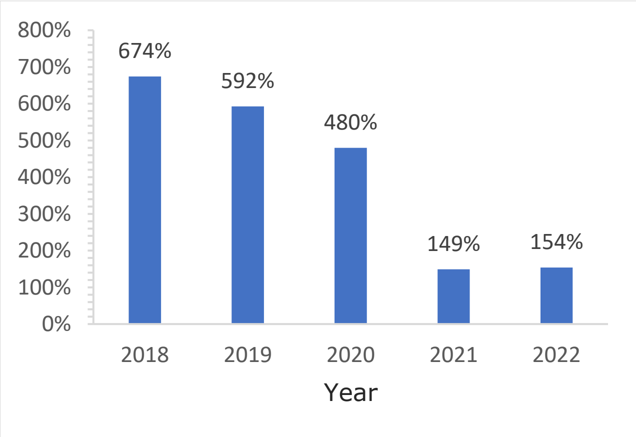

Figure 16. Utilization rate of *Decapterus macrosoma.*

Based on the graph above, it can be seen that the utilization rate of *D. macrosoma* has exceeded the sustainable exploitation level every year.

Conclusions. Purse seine is the dominant type of fishing gear used to catch *D. macrosoma*. The mean of the length class of *D. macrosoma* that was most caught was around 22 cm, with 552 specimens, and for the least caught specimens it was around 34 cm, with 0 fish. The sex ratio for female fish is 56%, more than male fish at 44%. The relationship between length and weight of female fish as a whole shows a negative allometric growth pattern ($b<3$; the weight increase is faster than the length increase). Fluctuations in the utilization rate of *D. macrosoma* can be caused by various factors, the decrease in catches may be due to a decrease in population size due to high fishing efforts in previous years. On the other hand, an increase in catch could be due to an increase in population size due to lower fishing effort in the previous year, or an increase in effort itself due to price incentives.

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Conflict of interest. The authors declare no conflict of interest.

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