Biological aspect of mackerel scad (*Decapterus macarellus* Cuvier, 1833) in Prigi waters Trenggalek Regency East Java Indonesia

G Bintoro, T D Lelono, D P Ningtyas
Faculty of Fisheries and Marine Science, Universitas Brawijaya
Email: gbintoro@ub.ac.id

**Abstract.** Mackerel scad (*Decapterus macarellus*) is one of the dominant catches in the Java Sea. Sustainability of Makarel scad resources (*D. macarellus*) needs to be maintained and managed optimally and sustainably. This research was conducted in Prigi Waters, Trenggalek East Java, starting December 2018 to September 2019 which aims to identify biological aspect and food composition of Mackerel scad (*D. macarellus*). The method used in this study is descriptive and uses a random sampling method. 1610 fish samples. Acquisition of Total length (TL) mackerel scad (*D.macarellus*) ranges from 16.8 - 35 cm and weighs between 42 - 328 grams. The Growth Pattern on (*D. macarellus*) is negative Alometric with the equation $W = 0.0163L^{2.8447}$. The ratio of male and female is 1: 1 The Gonad somatic index value is 1.41%. The value of Lm Female is 25,70 cm Lm male 25,92 cm and the value of Lc is 26,68 cm. $L_\infty$ Growth Parameter = 38.73, $K = 0.77, t_0 = -0.194$ years. The composition of mackerel scad in total sampling seen from the index of preponderance consisted of Zooplankton 51% (arthropods, molluscs, cnidaria, annelida, chordata) and 49% phytoplankton (ochrophyta, bacillarophyta, chlorophyta, cyanobacteria, protozoa, ciliopora, cyanophyta).

1. **Introduction**

Trenggalek, is an area located on the south coast of East Java Province which has a vast sea area of 35.6 km². Trenggalek Regency also experienced good growth in the fisheries sector. Based on production data from the Fisheries Port Where Center (PIPP) in 2018, Mackerel scad caught in Prigi Archipelago Fishingport are produced (in kilograms), which is 23.758 Kg. With the dominance of Mackerel scad in the waters of Prigi Bay is very large, causing flying fish relatively more desirable. Mackerel scad (*Decapterus spp*) is a pelagic fish resource that has economic value and makes a major contribution to fisheries production. With the dominance of Mackerel scad in the waters of the very large Bay of Prigi, it causes the Mackerel scad to be relatively more popular compared to other fish [1] one of which is Mackerel scad (*Decapterus macarellus*).

One of the biological resources in the waters of the Bay of Prigi is small pelagic fish. The types of fish included in the category of small pelagic fish resources include scad (*Decapterus spp*), anchovy(*Stolephorus spp*), Bali sardine(*Sardinella lemuru*), Fringescale (*Sardinella fimbriata*), Mackerel (*Rastrelliger spp*), and flying (*Cypsilurus spp*)[2]. In relation to its large role, the preservation of blue Mackerel scad resource (*D. macarellus*) needs to be maintained and managed optimally and sustainably.
2. Materials and method
This research was conducted using descriptive and random sampling method from December 2018 to September 2019 in the southern coast of Prigi waters, Trenggalek Regency, East Java. Primary data was obtained from sampling fish caught by purse seine and landed at Prigi.

Other primary data includes identification of food in the form of plankton in the fish stomach. Secondary data consists of Where obtained from the port office and fisheries journals to support primary data. In this study, the biological aspects of Mackarel scad (D. macarellus) were analyzed regarding the length and weight relationship, sex ratio, Gonad Maturity Level (GML), Gonado Somatic Index (GSI), length at first capture (Lc), length at first mature (Lm), and food composition. In addition, two parameters of growth are also assessed, namely the theoretical maximum length or asymptotic length (L∞) and the growth rate coefficient (K). The second estimation of L∞ and K will be assessed using Electronic Long Frequency Analysis (ELEFAN I) in the Fish Stock Assessment Application (FISAT II).

2.1. Length and weight relationship
Length and Weight Relationship data are assessed based on [3] allometric growth model with mathematical formula as follow:

\[ W = aL^b \]  

(1)

Where \( W \) = weight (gram); \( a \) = intercept; \( b \) = slope and \( L \) = total length (cm). This equation then transforms into a linear equation so that the form of the equation:

\[ \ln W = \ln a + b \ln L \]  

(2)

Allometric or isometric relationships were analyzed by the T-Test. If \( t \) count is higher than \( T \) table then the value of \( b \neq 3 \) or allometric. If the count is smaller than table then the value of \( b = 3 \) or isometric

2.2 Sex ratio
The analysis used to determine the sex ratio of male and female fish [4]

\[ \% \text{ Male} = \frac{\text{Number of Male}}{\text{Total male}} \times 100\% \]  

(3)

\[ \% \text{ Female} = \frac{\text{Number of Female}}{\text{Total female}} \times 100\% \]  

(4)

Then the sex ratio is analyzed using chi square analysis [5] with the formula:

\[ E_{ij} = \frac{(nio \times noj)}{n} \]  

(5)

Where \( E_{ij} \) = theoretical frequency expected to occur; \( nio \) = number of lines to \( i \); \( noj \) = number of columns to \( j \); and \( n \) = number of frequencies or value of observation.

2.3 Gonado somatic index
Gonado Somatic Index (GSI) can be analyzed using the formula below [5]:

\[ \text{GSI} = \frac{Bg}{Bt} \times 100\% \]  

(6)

Where GSI = gonad somatic index; \( Bg \) = gonad weight (gram); and \( Bt \) = body weight (gram).
2.4 Length at first mature (Lm)
The length at first mature analysis of the first gonad mature (length at first mature / Lm) using the formula [5]:

\[ Q = \frac{1}{1+e^{-a(L-Lm)}} \]  

(7)

Where Q = the long class fraction which is ripe gonad; 1 = maximum value that indicates 100% mature; e = 2.718; a = constant; L = long class interval; and Lm = length of fish when mature 50%

2.5 Length at first capture (Lc)
Lc is used to foresee the first maturity of gonads using the Sparre and Venema formula [5], as follows:

\[ y' = \frac{L}{\pi} Fc(x + dL) - \frac{L}{\pi} Fc(x) \]  

(8)

where \( Fc(x) \) is a normal distribution curve that has the equation:

\[ Fc(x) = \frac{n.dL}{\sqrt{\pi}} x \left[ \frac{(x-\mu)^2}{2s^2} \right] \]  

(9)

\[ \Delta \frac{Ln Fc(z)}{\pi} = a - b \times (L + \frac{dL}{2}) \]  

(10)

Where Fc= calculated frequency; n: number of observations; dL: class interval; s: standard deviation; \( \mu \): count average; and \( \pi \) : 3.1459

2.6 Growth parameters
The values in the growth parameters of the K, Loo and t0 values are obtained from the Von Bertalanffy equation [5] as follows:

\[ L(t) = L(\infty)(1-e^{-K(t-t0)}) \]  

(11)

Where \( L(\infty) = \) fish asymptote length (cm); K = growth rate coefficient (years); and \( t0 = \) theoretical age of fish at zero length (years)

Calculation the value of \( t0 \) can be done using the formula [7] as follows:

\[ \log(t0) = 0.3922 - 0.2752 (\log L(\infty)) - 1.038 (\log K) \]  

(12)

2.6.1 Length infinity (L(\infty)).
Analysis a Ford Walford plot was used because this plot can be used to obtain a fast estimate of the \( L(\infty) \) value with the following formula [5]:

\[ L(\infty) = \frac{a}{(1-b)} \]  

(13)

Where : \( L(\infty) = \) theoretical maximum length of fish (cm); a = intercept; and b = slope.

2.6.2 Value of K.
The value of K can be searched through the equation as below:

\[ K = \left( \frac{1}{\Delta t} \right) \times \ln b \]  

(14)

Where K = Growth rate coefficient (per years); \( \Delta t = \) difference from the relative age of fish in the following year; b = slope
2.6.3 Rate of mortality.
Total mortality can be estimated using data derived from the previous analysis using \( L \) and \( K \). The following is a calculation formula [5].

\[
Z = \frac{K(L_{\infty} - L)}{L - L'} \tag{15}
\]

Where \( Z \) = total mortality; \( K \) = growth rate coefficient (per years); and \( L_{\infty} \) = theoretical maximum length (cm); \( L' \) = the smallest size of fish (cm); and \( L \) = size of average fish length (cm).

2.6.4 Natural mortality.
Determination of natural mortality (\( M \)) can be predicted by using Pauly’s empirical formula [6], from the equation as follow:

\[
\ln M = -0.0152 - 0.279 \ln L_{\infty} + 0.6543 \ln K + 0.463 \ln T \ldots 
\tag{16}
\]

Pauly suggested that fish species that have a habit of clustering in their calculations were multiplied by 0.8 so that the estimated value was 20% lower.

\[
M = 0.8 \times e^{-(-0.0152 - 0.279 \ln L_{\infty} + 0.6543 \ln K + 0.463 \ln T)} \tag{17}
\]

Where \( M \) = Natural mortality; \( L_{\infty} \) = Theoretical maximum length (cm); \( K \) = growth rate coefficient (per year); and \( T \) = Average sea surface temperature (°)

After values of total mortality (\( Z \)) and natural mortality (\( M \)) are obtained, then fishing mortality (\( F \)) can be found where \( Z = F + M \).

2.6.5 Exploitation rate.
Value of the Exploitation rate can be calculated using as follows:

\[
E = \frac{F}{F + M} \tag{18}
\]

or

\[
E = \frac{F}{Z} \tag{19}
\]

If:

\[
E > 0.5: \text{Over Fishing}
\]

\[
E = 0.5: \text{Maximum Sustainable Yield (MSY)}
\]

\[
E < 0.5: \text{Under Fishing}
\]

2.7 Type of plankton, food composition and index of preponderance
The type of food that is preferred by the percentage of a type of food to the whole food eaten by fish. This method is a combination of the Event Frequency method and the Volumetric method [5]:

\[
IP = \frac{Vi \times Oi}{\sum Vi \times Oi} \times 100\% \tag{20}
\]

Where \( Vi \) = Proportion of food volume to \( i \) (%); \( Oi \) = Proportion of frequency of occurrence of food to \( i \) (%); \( \Sigma Vi \times Oi \) = Total \( Vi \times Oi \) and all kinds of food.

3. Results
The fish sample obtained was 1610 fish and was used for length and weight measurements. Then for the observation of GML, GSI, and (Lm) first used 861 fish samples and observed the composition of
food used 250 fish samples. Fish lengths ranged from 16.8 cm to 35 cm and the weight of fish ranged from 42 to 328 grams. Length frequencies consisted of several fish length class sizes (Figure 1).

![Length frequency](image1)

**Figure 1.** Length frequency

### 3.1 Length and weight relationship

The equation for Length and Weight Relationship analysis \( W=0.0163L^{2.8447} \) means the length of influence of fish weight by 79% (Figure 2). The results of the T-test (T-test) show that the value of \( t \) count is 4.3500 and \( t \) table 1.9614 is allometric. That means \( t \) count> \( t \) table 0.05 where \( b \neq 3 \) has negative allometric growth patterns, long growth body is more dominant than heavy body growth.

![Length-weight relationship](image2)

**Figure 2.** Relationship between length and weight of mackerel scad (*D. macarellus*)

### 3.2 Sex ratio

Sex ratio is used for comparison of the number of male and female fish in a population. The fish samples obtained consisted of 431 male and 430 female. The percentage of male and female fish was 50.1%, 49.% (Figure 2). Chi square analysis obtained male and female 1: 1.1 with \( x^2 \) count is 0.0002243 and \( x^2 \) table value is 3.841 means \( x^2 \) count < \( x^2 \) table, there is no real difference between the ratio obtained with the expected ratio, ratio Monthly sex varies 1: 1.3 (December), 1: 1 (January), 1.1: 1 (February), 1: 1.4 (March), 1: 4 (April), 1: 1 (June ), 1: 1 (July), August (1:1), September (1:1).
The ratio of male and female is balanced or more females can be interpreted that the population is sustainable.

![Circle chart showing the ratio of male (49.9%) and female (50.1%) mackerel scad.](image)

**Figure 3.** Ratio of mackerel scad (*D. macarellus*)

### 3.3 Gonad maturity level (GML)

The results of the study were 861 Mackerel scad (*D. macarellus*). The number of male or female fish has a variety of GML (I-V). From the observations of the frequency of male and female female GML (Figure 4), it was indicated that in December 2018 - September 2019 it was dominated by fish with mature gonads GML (III-V) (Figure 5).

![Bar chart showing the frequency of GML mackerel scad (*D. macarellus*).](image)

**Figure 4.** Frequency of GML mackerel scad (*D. macarellus*)

![Circle chart showing the proportion of mature (56%) and immature (44%) mackerel scad.](image)

**Figure 5.** Proportion of gonad maturity level mackerel scad (*D. macarellus*)
In this study it was found that the proportion of gonadal immature fish was 44% (376 fish) of mature gonads producing 56% (485 fish).

3.4 Gonado somatic index (GSI)
The Gonado Somatic Index (GSI) describes the Gonad Maturity Level. The GSI value in Prigi waters varies every month. The highest GSI was obtained in February 2019, the lowest was obtained in December 2018 (Figure 6). The average mackarel scad GSI obtained in December, January, February, March, April, June, July is 0.99%, 1.82%, 1.88%, 1.15%, 1.31%, 1, 2%, 1.15% each (Figure 5). The smallest GSI value occurred in January and March with a value of 0.03%, while the largest in February with 6.58%. Total GSI average 1.41 %%.

![Figure 6. Gonad Somatic index Mackerel scad (D. macarellus)](image)

3.5 Length at first mature (Lm)
Length at first mature (Lm) used to estimate the length of the fish when gonads mature first. Based on the analysis data, it was found the Lm Female value of 23.93 (Figure 7) and Lm Male is 24.03 cm (Figure 8) for Mackerel scad (D. macarellus).

![Figure 7. Lm Female (D.macarellus)](image) ![Figure 8. Lm Male (D.macarellus)](image)

3.6 Length at first capture (Lc)
Length at first capture (Lc) is used to predict the first time the fish is caught. From the analysis of data calculations, it was found that Lc was 26.68 cm (Figure 9). Lc value is greater than Lm This means that flying fish caught in Prigi waters are worthy of capture. Lc values in several research locations vary. One of the differences in Lc values from the catchment area and awareness of the fishermen.
3.7 Growth rate
Several growth rate parameters have been calculated. They were values of asymptotic length ($L_\infty$), growth rate coefficient ($K$) 38.73 cm and 0.77 per year respectively (Figure 10) and $t_0 = -0.194$ years. The fish growth rate coefficient can be said to be high if it is in the range of 0.5-1. Based on the acquisition of K values, it can be assumed that ($D. macarellus$) have a growth rate of 0.77 per year and are short-lived because to reach asymptotic length requires a short time.

$$L_t = 38.73 (1 - e^{-0.77(t+0.1944)})$$

3.7.1 Analysis of mortality.
From the results of research data analysis of mackerel scad ($D. macarellus$) in Prigi waters in East Java, total mortality ($Z$) of 3.0 per year was obtained, while natural mortality values ($M$) were analyzed using Pauly’s formula [6] by entering the value $K = 0.77$ per year, $L_\infty = 38.73$ cm and $T = 29.19$ °C. thus the estimated value of $M = 0.28$ per year is obtained while the catch mortality rate ($F$) is obtained by ($F = Z - M$) so that the estimated value of $F = 2.71$ per year. The mortality caused by arrest is greater than natural mortality ($F > M$), so the fishery status in these waters is stated to be more catch or over fishing.

3.7.2 Analysis of exploitation.
Based on the arrest mortality value ($F$) with total mortality value ($Z$) in Prigi Trenggalek Waters in East Java, the exploitation rate ($E$) can be obtained by entering the formula $E = F / Z$ so that an $E$ value of 0.905 per year can be obtained. From the results of these calculations it can be concluded that the
status of fisheries in these waters is declared over Exploited. This is in accordance with the opinion stated by Pauly (1983) which explains that if the value of E or the rate of exploitation is more than 0.5, the status of fisheries in the region is stated to be Over Fishing. Because E > 0.5, then the waters can be declared over fishing.

3.8 Food composition
The results of the gastric composition of Mackarel scad (D. macarellus) found food consisted of arthropod phylum, ochrophyta, chlorophyta, bacillariophyta, mollusca, protozoa, cyanobacteria, cnidaria, cyanophyta, annelida, chordata and ciliopora. The dominant analysis index shows the main food index of food (D. macarellus) in Prigi waters consisted of filum Arthrophoda (IP > 65%), complementary food (IP 4-25%) from phylum Ochrophyta, supplementary food (IP < 2.2%) from phylum chlorophyta, bacillariophyta, mollusca, protozoa, cyanobacteria, cnidaria, cyanophyta, annelida, chordata and ciliopora (Figure 11). The type of food obtained, it can be concluded that Mackarel scad (D. macarellus) is Plankton feeder because food in the stomach is dominated by plankton.

![Figure 11. Index of propadance (D.macarellus)](image)

4. Discussion
Analysis of the relationship between length and weight of Mackarel scad (D. macarellus) negative allometric growth patterns. Several factors that influence the body shape of the fish. These factors are food availability, eating habits and water conditions [3]. Environmental conditions support the growth of fish, so other factors can also influence differences in the value of b is the availability of food and the level of maturity of the gonad. Other factors that affect fish loss are fish eating habits, food availability in the waters, fish growth, and aquatic conditions [7].

The ratio of male and female in nature is estimated to be close to 1: 1, which means that the number of male and female fish caught is relatively equal. Sex ratio is important to know because it affects the stability of the fish population in nature. Balance of sex ratio 1: 1 is an ideal condition in a waters [8]. Sex ratio is important to know because it can affect the condition and stability of the fish population so that its sustainability is maintained, if the number of male and female fish is balanced or sustainable.
Gonad Maturity Levels indicate the level of sexual maturity of fish. Most metabolic results are used during the gonadal development phase. The development of gonads is influenced by external and internal factors. External factors, namely temperature and food, internal factors, namely steroid hormones and gonadotropins, which function to regulate gonadal maturity [9]. The development of gonads in female fish is 10-25% of body weight, while male fish ranges from 5-10% [10].

The GSI is a comparison between the weight of the gonad and the body weight of the fish. Changes in the value of GSI relate to the stage of egg development. The gonad will reach its maximum when the fish spawn and then decrease during spawning until it is finished. GSI smaller than 20% is a group of fish that can spawn more than once per year [11]. It can be concluded that Mackarel scad (D. macarellus) landed at Prigi Trenggalek Fishingport uses purse seine fishing equipment including fish that can spawn more than once per year. The size of the fish at first maturity is usually influenced by food availability, temperature, light, and environmental factors in each habitat.

The results of differences in the length of fish gonad mature can be influenced by several factors including the different locations of the distribution of Mackarel scad (D. macarellus) and the magnitude of the catch rate at each location. Environmental conditions have an impact on the size of fish when gonads mature for the first time. Fish that can be caught is defined as a fish that has a length greater than the first mature gonad (long when it first gonads mature) [12]. Length at first capture (Lc) used to predict the length of the first time the fish is caught. In this study the value of Lc > Lm means that the size of the fish caught at this location is greater than the size of a gonadal ripe fish. One of the factors that can affect the size of Lc is the fishing gear used in taking sample fish [13].

Growth is an increase in length and weight at one time. Growth affects fish stocks in an area. The higher the K value, the faster the fish will reach L∞ and the fish will die faster [5].

The rate of catching can be of relatively high value due to the density of fishing efforts carried out by a waters, causing relatively little production or catch. So that over-exploitation can threaten the survival of a previously existing fish resource [14]. Observations of elevated fish stomach (D. macarellus) found the main types of food plankton, supplementary food and supplementary food obtained by comparison of fish gastric contents by 49% (phytoplankton) and 51% (Zooplankton). The food compositions consisted of primary (phyllum arthropod with IP > 65%), complementary (ochrophyta with IP 20.8%) and supplementary (phyllum chlorophyta, bacillariophyta, molluscs, protozoa, cyanobacteria, cnidaria, cyanophyta, annelida, chordata and ciliopora with IP <4%). Mackarel scad (D. macarellus) in Prigi is included as plankton feeder due to domination of plankton type in fish stomach.

5. Conclusion
The length weight relationship was Isometric with equation W=0.0163L^{2.8447}. The ratio of male and female sex ratios was 1:1. Proportion between mature and immature was 56% and 44% respectively. The lowest value of GSI occurred in December 2018 (0.69%) and the highest in February (1.43%). Estimated value of Lc was 26.68 cm. While values of Lm female and male were predicted to be 23.93 and 24.03 cm respectively. Fishing gears have selectively caught the fish due to higher Lc than Lm. Growth rates of fish were L∞ = 38.73 cm, K = 0.77 / year and t₀ = -0.194 years. The food compositions consisted of primary (phyllum arthropod with IP > 65%), complementary (ochrophyta with IP 20.8%) and supplementary (phyllum chlorophyta, bacillariophyta, molluscs, protozoa, cyanobacteria, cnidaria, cyanophyta, annelida, chordata and ciliopora with IP <4%). Mackarel scad (D. macarellus) in Prigi is included as plankton feeder due to domination of plankton type in fish stomach.

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