Growth patterns of skipjack tuna (*Katsuwonus pelamis, linnaeus 1758*) caught by troll line in Prigi waters, Trenggalek East Java Indonesia

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Abstract. Skipjack tuna (*Katsuwonus pelamis*) is an important pelagic fish species caught in tropical and subtropical waters of the Pacific, Atlantic, and Indian oceans. Skipjack tuna (*K. pelamis*) is also a high economic fisheries resource in Prigi waters which is caught by troll line. High market demand results in high levels of exploitation. This study aimed to identify the length-weight relationship and biological reproduction of skipjack tuna in the Prigi waters. The research was conducted in the sampling period between December 2019 - April 2020 with total samples obtained as much as 1642 fish and was analyzed using linear regression. The results informed that the length-weight relationship of skipjack tuna was positive allometric with equation $W= 0.007FL^{3.223}$ which means that the fish has a fat body. The sex ratio between male and female fish is 1:1. While gonad maturity level obtained in this study is mostly in GML 1 and GML 2 which indicates that the catches were dominated by immature fish, so it is necessary to limit fishing effort so that sustainability of the skipjack tuna (*K. pelamis*) resource can be managed.

1. Introduction

Skipjack tuna (*Katsuwonus pelamis*) is an important commercial species with high productivity and mainly caught in tropical and subtropical waters of the Pacific, Atlantic, and Indian oceans. It is known that more than 70% of the catches of skipjack tuna (*K. pelamis*) came from the western and central Pacific Ocean (WCPO) produced by purse seine fishery [1].

The discussion of aspects of biology has always been a hot topic around the world. The information about biology will make easier for the fisheries officers to determine fish growth pattern, especially skipjack tuna (*K. pelamis*). Some literatures and journals explain that the biological aspects such as length-weight relationship and the reproductive of skipjack tuna (*K. pelamis*) is very interesting to discuss because the skipjack tuna (*K. pelamis*) is considered as a robust species due to its high productivity and life history parameters [2].

Indian Ocean of the Indonesian Fisheries Management Area (FMA 573) has great tuna resources. Nowadays, tuna fishing activities in FMA 573 are carried out using a variety of fishing gear such as longline, trolling line, and pole and line. Fish aggregating devices (FADs) is an additional fishing equipment that are used by trolling line and pole and line in order to make easier fishing activity. The estimation of the utilization level of the maximum sustainable production potential of skipjack tuna (*K. pelamis*) in FMA 573 is a moderate status. fishery management plan (FMP) for tuna, skipjack, and little tuna. The FMP is expected as a reference for the sustainable management of Indonesian tuna
fisheries. However, in practice, the FMA could not be properly implemented because of various problems in the activities of tuna fisheries, such as the capture immature small tuna, low fish quality, and increasingly distant fishing ground [3].

Skipjack tuna (K. pelamis) does not follow clear spawning or feeding migration patterns. Home range movements are affected by environmental conditions, such as prey availability, temperature, and dissolved oxygen concentration. Currently, skipjack tuna catches represent almost half of the total tropical tuna catch in the Indian Ocean. Although the skipjack tuna is considered to have a high resilience against overfishing due to the fast growth rate and the year-round spawning, the decreasing trend of surface fisheries catches since 2006 led to concern about the sustainability of the present level of exploitation [4].

Trolling line is one of the leading fishing gears used for catching the skipjack tuna (K. pelamis) in Prigi waters. This fishing gear is operated by using 10 to 20 Gross tonnage (GT) vessels. There were 91 units troll line in operation and tended to increase their number every year. This occurs because the troll line has many advantages, namely the relatively small cost when compared to other fishing gears, the quality of the fish caught by trolling line is classified as high quality, and the trolling line fishing operation is independent of the season fish [5] because in the Prigi waters it is certain that the fishing area of the trolling line is in the FAD area. This has caused the emergence of a big problem, namely the catches are dominated by small fish [6].

This research aimed to identify length-weight relationship and reproductive of skipjack tuna (K. pelamis) caught in Prigi waters. These data can be used as a basis for analyzing the status of fish resources in the southern waters of East Java Province, especially in Trenggalek area such as Prigi waters.

2. Materials and method
Quantitative descriptive and random sampling methods were used in this research which was conducted from December 2019 - April 2020 in the Prigi waters, Trenggalek, East Java. Primary data collection was done toward fish caught by troll line and landed at Prigi Archipelago Fishing Port (AFP). Variables to be measured were length, weight, gonad maturity, and sex. The samples of skipjack tuna (K. pelamis) were taken randomly from troll liners catch landed in Prigi AFP. The sample data were taken by considering cost-efficiency. At the same time, secondary data were also collected from books, annual reports, and supporting literature. The data were analyzed using linear regression.

Other primary data include identification of food in the form of plankton in the fish stomach. Secondary data consist of fisheries journals to support primary data. In this study, the biological aspects of skipjack tuna (K. pelamis) were analyzed regarding the length and weight relationship, sex ratio, gonad maturity level (GML), and gonad somatic index (GSI).

2.1. Length weight relationship
The length and weight relationship can be analyzed based on formula [7] as follow:

\[
W = aL^b
\]

Where: \(W\) = weight (gr), \(L\) = length (cm), \(a\) = intercept, \(b\) = slope

The \(a\) and \(b\) values in the length weight relationship analysis are obtained from the form of linear equations because a lot of field data is strongly influenced by the environment, unpredictable field condition, and high field data variable. The form of the linear equation is \(\ln W = \ln a + b \ln L\). In order to ensure the slope or \(b\) value, then the t test is performed with a confidence interval of 95% (\(a = 0.05\)) [8]. Testing the value of \(b = 3\) or \(b \neq 3\) (partial test) is carried out with the hypothesis:

- **H0** is the value of \(b = 3\), the growth pattern is isometric, which means that the length and weight relationship is balanced.
- **H1** is \(b \neq 3\), the growth pattern is allometric, which means that the length and weight relationship is not balanced.
  - Positive allometric if the value of \(b>3\) (weight growth is faster than length growth).
Negative allometric if the value of $b<3$ (length growth is faster than weight growth).

2.2. Sex ratio
The calculation of the sex ratio is determined from the total number of samples obtained during the study and calculated based on the number of individual males and females each month, with the following mathematical formula [9].

$$X = \frac{J}{B}$$  \hspace{1cm} (2)

Where: $X =$ sex ratio, $J =$ The number of male sample fish, $B =$ The number of fish sampled from females.

The value of sex ratio can be calculated by comparing the number of individual females with the number of individual males using the Chi-Square test [10], with the following mathematical formula.

$$X^2 = \sum_{i=1}^{k} \left( \frac{o_i - e_i^2}{e_i} \right)$$  \hspace{1cm} (3)

Where: $o_i =$ The observed male and female values, $e_i =$ Expected value, or a balance condition.

From these calculations, it can be concluded that if the value of $X^2$ count $<X^2$ tab, $H_0$ is accepted which means that there is no significant difference between the ratio obtained and the expected ratio. While if $X^2$ count $>X^2$ tab, $H_0$ is rejected which means that there is a significant difference between the ratio obtained and the expected ratio.

2.3. Gonad maturity level (GML)
Gonad maturity is useful for estimating reproductive potential, spawning biomass stock, and potential recruitment. Determination of fish gonad maturity level refers to gonad maturity which indicates that fish are ready to spawn [11]. The gonad maturity level is divided into 5 phases, namely immature, maturing virgin/recovering spent, ripening, ripe, and spent (Table 1).

| GML            | Female | Male                        |
|----------------|--------|-----------------------------|
| I  (Immature)  | The ovaries and testes are about 1/3 the length of the body cavity. Ovaries pink, translucent. | Whitish testicles. The ovaries are not visible to the naked eye. |
|                | The ovaries and testes are about ½ the length of the body cavity. Ovaries pink, translucent. | Whitish testicles, more or less symmetrical. The ovaries are not visible to the naked eye. |
| II (Maturing virgin/Recovering spent) | The ovaries and testes are about 2/3 of the body cavity. Ovary reddish-yellow colour with a granular appearance | Whitish testicles until creamy. No transparency or visible ovaries. |
| III (Ripening) | The ovaries and testes range from 2/3 to the length of the body cavity. The ovaries are a striking orange-pink colour. Blood vessel. Large transparent, mature ovaries are visible. | The testes are white, soft |
| IV (Ripe)     | The ovaries and testes shrink by about ½ the length of the body cavity. Loose walls. The ovaries may contain spawning remnants | Blood shoot and flabby testicles. |
| V  (Spent)    |        |                             |

2.4. Gonad somatic index (GSI)
The gonad somatic index (GSI) can be calculated by comparing the gonad weight with the body weight including the gonads which are in percent [12]. The formula to determine the GSI is as follow:
Where: GSI = Gonad somatic index, \(W_g\) = Gonad weight (gram), \(W_b\) = Body weight (gram)

3. Results and discussion
The result of measuring the length and weight of fish in skipjack tuna (K. pelamis) during the study obtained 1642 samples with fork length (FL) ranging from 28-55 cm and fish weight between 298 grams-3012 grams. The dominant samples were occupied by interval class 36 cm. Length frequencies consisted of several fish length class sizes (Figure 1)

![Figure 1. Length frequency](image1)

3.1 Length and weight relationship
The relationship between length and weight is estimated by following the equation \(W = a L^b\), from linear regression analysis the a value is 0.007 and the b value is 3.223 so that the equation is \(W = 0.007L^{3.223}\) (Figure 2). From the results of the T-test measurement, the t-value is 8.890 and the t-table value is 1.961 which means that the t-count value is greater than the t-table where the value of b>3 which means that the growth pattern of skipjack tuna (K. pelamis) has a positive allometric pattern where growth weight is faster than growth length.

![Figure 2. Length and weight relationship of skipjack tuna (K. pelamis)](image2)
The results of the length-weight analysis obtained the value of b was 3.223 and the results of the t-test analysis obtained a t-count was 8.890 and t-table value was 1.961, which means that t-count is greater than t-table (b > 3) so the growth pattern of skipjack tuna (K. pelamis) is positive allometric which means that the growth weight is faster than the growth length so the fish has fat body. The results of the analysis of length and weight in several waters may be different, this is due to external and internal factors. Internal factors such as diseases and parasites that easily affect fish growth. If the digestive organs of the fish and other organs are attacked, the efficiency of the food that functions for growth is reduced. External factors such as the presence or absence of food in the waters, water temperature, dissolved oxygen, and water quality that do not support fish habitat will inhibit the growth process [13].

3.2 Sex ratio
The total sample fish obtained in the analysis of the sex ratio of skipjack tuna (K. pelamis) was 54 fish, consisting of 24 male fish and 30 female fish. The ratio percentage between male and female skipjack tuna (K. pelamis) was 44% and 56% respectively, so that a ratio was 1 : 1.27. Based on Chi-Square test, the value of $X^2$ is calculated as 0.025 which is lower than value of $X^2$ table (3.841) (Figure 3).

![Figure 3. Sex ratio of skipjack tuna (K. pelamis)](image)

The sex ratio of skipjack tuna (K. pelamis) studied showed the ratio of male and female skipjack tuna (K. pelamis) with their respective values of 44% and 56%, so that the ratio closed to 1: 1. Based on Chi Square analysis, it is known that the value of the $X^2$ calculation is 0.025 and the value of the $X^2$ table is 3.841. From the Chi Square test, the calculated $X^2$ value is less than the $X^2$ table value hence there is no significant difference between the ratio obtained and the expected ratio.

Although the proportion of sex between males and females is a bit imbalance, the skipjack tuna (K. pelamis) resources in Prigi waters can still be said to be balanced. This is because the reproduction process can still take place. The imbalance of the proportion of male and female sex in various regions is influenced by many factors, including growth rate, growth rate, behavior patterns such as fish migration, both for feeding and spawning [14]. The balanced sex proportion between male and female can indicate that one male fish will fertilize one female. This allows the maximum fertilization process to occur during the mating season. The ratio of sex ratios of tuna fish caught in different waters can vary based on the month and fishing season. The difference in the number of individual females and males is influenced by several factors, such as gender-based mortality, different growth rates, and one of the sexes of skipjack tuna (K. pelamis) is vulnerable to fishing [15].

3.3 Gonad maturity level (GML)
The gonad maturity level (GML) of male and female skipjack tuna (K. pelamis) was dominated by immature fish (Figure 4). The proportion of immature males was about 76% and the proportion of
immature females was 67%. In the study, there were no samples of skipjack tuna (*K. pelamis*) with GML V. In total, proportion of immature and mature fish was 70% and 30% respectively.

![Figure 4. Gonad maturity level of skipjack tuna (*K. pelamis*)](image)

The GML is used to determine whether the fish caught are fish that are not spawning, the highest GML value will be obtained when the spawning season occurs. In the study, no samples of skipjack tuna (*K. pelamis*) were found with GML V, it is suspected that the sampling month is the spawning season of skipjack tuna and it is also suspected that the fish samples taken are fish that have spawned and have been filled with new embryos. In the waters of the Indian Ocean the peak season for skipjack spawning starts from December to March. When going to the spawning process of skipjack tuna will move down into the deeper sea, so the chance of catching fish in GML V condition is very small. [16]. If the dominant catch is at GML IV both male and female, the fish just start to conduct spawning activity [15].

### 3.4 Gonad somatic index (GSI)

The results of the GSI analysis have different values for each sampling. The average GSI in December 2019 was obtained at 0.59%, in January 2020 the GSI value was 0.30%, in February 2020 it was 2.08% and in March 2020 the GSI value was obtained at 1.81% (Figure 5).

![Figure 5. Gonad somatic index (GSI) of skipjack tuna (*K. pelamis*)](image)

The GSI of skipjack tuna (*K. pelamis*) obtained during the study was classified as small, with an average GSI value of 0.24%. Types of fish that have a GSI value of less than 20% are included in the category of fish that spawn more than once a year, so it is assumed that the skipjack tuna (*K. pelamis*) spawns more than once per year [17]. GSI values can reach a maximum value just before the fish
experience spawning. The GSI analysis can be used to draw fish reproductive strategies [18]. There are two factors that affect the spawning season in fish, namely internal and external factors. The internal factors include fish age, and hormonal conditions, while external factors consist of temperature, waters and types of food [19].

4. Conclusion
The growth pattern of skipjack tuna (K. pelamis) in Prigi waters is positive allometric with equation W= 0.007FL^{-0.23}. The gonad maturity levels occur mostly at GML 1 and GML 2 which means that the catches are dominated by immature fish. The reproductive aspect including the sex ratio between male and female indicates a balanced condition. While value of GSI ranges from 0.59% to 2.08%, hence the fish has ability to conduct reproduction activity more than once a year.

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