

# Skipjack tuna's (*Katsuwonus pelamis*) biology and its fisheries status in the Banda Sea, Maluku, Indonesia

*by* Cek Turnitin

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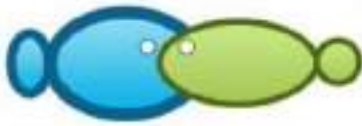
**Submission date:** 26-Jun-2023 12:43PM (UTC+0800)

**Submission ID:** 2122748872

**File name:** 13.pdf (455.46K)

**Word count:** 6113

**Character count:** 29610



## Skipjack tuna's (*Katsuwonus pelamis*) biology and its fisheries status in the Banda Sea, Maluku, Indonesia

<sup>1</sup>Maman Hermawan, <sup>1</sup>Jerry Hutajulu, <sup>1</sup>Syarif Syamsuddin, <sup>1</sup>Danu Sudrajat, <sup>1</sup>Yusrizal, <sup>1</sup>Erick Nugraha, <sup>1</sup>Aman Saputra, <sup>2</sup>Ratna Suharti, <sup>2</sup>Mira Maulita, <sup>2</sup>Firman Setiawan

<sup>1</sup>Faculty of Fishing Technology, Jakarta Technical University of Fisheries, South Jakarta, Indonesia; <sup>2</sup>Faculty of Fishery Resources Management, Jakarta Technical University of Fisheries, South Jakarta, Indonesia. Corresponding author: M. Maulita, maulita.stp@gmail.com

**Abstract.** *Katsuwonus pelamis* fish is a marine biological resource that has a quite high economic value in Indonesia. A potential fishing ground for large pelagic fish in eastern Indonesia is the Banda Sea. This study aimed to examine the aspects of biology and the management of *K. pelamis* exploitation in the Maluku region. The research was conducted in Maluku province for 90 days starting from March 4<sup>th</sup> to May 25<sup>th</sup> 2019. The method used was the purposive sampling and the data collected were primary data and secondary data. *K. pelamis* in the Banda Sea had a maximum sustainable yield (MSY) value of 57,837 tons with a fishing effort of 202,473 trips and the maximum economic yield (MEY) value was at 48,856 tons for a fishing effort of 122,732 trips. The study provided data on the frequency distribution of *K. pelamis* with the shortest fork length (FL) being 28.5 cm and the longest being 77.3 cm. The calculation of the growth pattern of large pelagic fish was carried out using the  $t_{max}$  ( $t_{max}=0.05$  tab) at a 95% confidence interval ( $\alpha=0.05$ ). The growth pattern obtained for *K. pelamis* was positive allometric. The sex ratio obtained was 1 male:1 female. The level of gonadal maturity was dominated by GML II (39%). *K. pelamis* caught with the purse seine have the first caught size ( $L_c=40.12$  cm) > size at first maturity ( $L_m=44.81$  cm). The actual catch of 70,251 tons showed that the species utilization has exceeded the maximum value of sustainable potential and, economically, the catch of *K. pelamis* has passed the MEY condition. The *K. pelamis* fisheries increase their production, with a low level of gear selectivity, so that there is a need for regulation of fishing gear and supervision.

**Key Words:** sex ratio, fork length, total weight, gonadal maturity level.

**Introduction.** Indonesian waters are considered to have living fish resources with the highest level of biodiversity (Sugara et al 2022; Yaskun & Sugiarto 2017; Hutomo & Moosa 2005). These resources cover at least 37% of the world's fish species (Mahmud et al 2021; Adnyani et al 2019). The resources of skipjack tuna (*Katsuwonus pelamis*) are grouped into large pelagic fish resources, including tuna (*Thunnus* sp.) and mackerel (*Euthynnus affinis*) (Jakson et al 2014; Bintoro et al 2022; Lintang et al 2012). *K. pelamis* are fishes products of interest for the general consumers and of a high economic value (Hutajulu et al 2019; Afriliani et al 2020; Geni et al 2016). Waters in eastern Indonesia are known as centers of *K. pelamis* production (Manurung 2016). One of the waters that has become a potential fishing ground for large pelagic fish in Eastern Indonesia is the Banda Sea (Hidayat et al 2014). The Banda Sea is the waters of the Eastern Indonesian Region which is included in the waters of the West Pacific Ocean and is bordered by the Indian Ocean (Chodriyah & Nugraha 2013). The Banda Sea became a potential fishing area for *K. pelamis* in Maluku Province (Tadjuddah et al 2017; Satrioajie et al 2018) throughout the year (Tangke et al 2014).

*K. pelamis* is a type of fish that belongs to the Scrombidae family (Afifi et al 2022; Mardlijah et al 2021; Chakma et al 2020). The Scrombidae family basically occurs in marine waters and is classified as pelagic fish (Ollé et al 2022; Paulangan et al 2020). Based on

their size, tuna is divided into two groups: *Thunnus* species are grouped into large tuna and *K. pelamis* species are classified as small tuna (Nugraha et al 2020; Chodrijah 2011). Exploitation of this resource is carried out by various forms of fishing activities, including purse seine, pole and line and handline (Jaleel & Smith 2022; Mardijah et al 2021; Widodo & Nugrah 2009). Due to the magnitude of the potential and to the condition of the available large pelagic fish resources, it is necessary to study the status of large pelagic fisheries, especially those targeting *K. pelamis* in the Banda Sea.

This study aimed to examine several aspects of *K. pelamis* including: a) biological aspects, in particular the length-weight relationship, b) fisheries characteristics, including production trends, fishing effort, fishing grounds, fishing season, fishing gear and CPUE and c) the management of the *K. pelamis* populations and their exploitation, which includes the calculation of the catch rate, maximum sustainable yield, maximum economic yield, and the number of allowed catches in the Maluku region.

## Material and Method

**Research sites.** The research was conducted for 90 days, from 4 March to 17 May 2019 in the Banda Sea. Data collection was carried out at several sampling points as shown in Figure 1.



Figure 1. Map of research locations.

The tools and materials used in this study are as follows: ruler, tape measure, digital scales, camera, stationery, identification label, and several samples of *K. pelamis*.

**Data retrieval method.** In this study a survey method was used, namely by observing fish samples in the field. Determination of locations and fishing gear was carried out by purposive sampling, namely by collecting data deliberately according to the desired conditions (Mukhsin et al 2017), while the determination of respondents was carried out by accidental sampling. Data collection for *K. pelamis* sampling was carried out using the simple random sampling method, by measuring the fork length, total weight, sex and gonadal maturity level of 10% of the total catch. Secondary data were periodic data (time series) of catches and fishing effort for 5 to 10 years.

**Length frequency distribution.** Frequency distribution was obtained by determining the class interval, median class and frequency in each length group. The length frequency distribution that has been determined with the same class intervals can then be put in a diagram to show the results.

**Length-weight relationship.** The model used in estimating the relationship between length and weight is an exponential relationship with the following equation (Andamari et al 2012):

$$W = aL^b$$

Where:

W - weight of fish (g);

L - standard fish fork length (cm);

A - the constant number or intercept of the regression calculation;

B - exponent or tangential angle.

To determine the value of a and b, a linear regression analysis is needed by considering the logarithm of the formula above. The linear equation becomes:

$$\ln W = \ln a + b \ln L$$

Then a simple linear equation can be made:

$$Y = a + bX$$

Where:

Y - dependent variable;

X - free change;

a' - antilog intercept;

b - slope (slope).

The b values,  $b < 3$ ,  $b = 3$  and  $b > 3$ , according to Effendie (1979), discriminate among the allometric type, as follows:

- 1) If  $b < 3$ , then the increase in length is faster than the increase in weight; it is called negative allometric
- 2) If  $b > 3$ , then the weight gain is faster than the increase in length; it is called positive allometric
- 3) If  $b = 3$ , then the increase in length and weight gain are balanced, which is called isometric

**Sex ratio.** Comparison of the sex of the biota was carried out by visual observation of a number of male and female individuals obtained as samples at the study site. The sex ratio is calculated using the formula (Diningrum et al 2019):

$$X(\%) = \frac{X}{(X+Y)} \times 100$$

$$Y(\%) = \frac{Y}{(X+Y)} \times 100$$

Where:

X - number of male fish;

Y - number of female fish.

After the sex ratio in percentage is obtained, comparisons are carried out to find out whether there is a significant difference between the male and female population, by using the 'X<sup>2</sup>' (chi square) test, with the formula (according to Effendie 1979):

$$\chi^2 = \frac{(f_o - f_h)^2}{f_h}$$



Where:

$\chi^2$  - chi square;

$f_o$  - observed biota frequency;

$f_e$  - expected biota frequency.

The  $\chi^2_{count}$  value is obtained from this calculation, then the value is compared with the table of  $\chi^2_{table}$  value, with a 95% confidence level and the degrees of freedom (db) = 1, with  $H_0$  hypothesis:

$H_0$  = no significant difference between the number of male and female fish

$H_1$  = there is a significant difference between the number of male and female fish

If,  $\chi^2_{count} < \chi^2_{table}$  =  $H_0$  is accepted,  $H_1$  is rejected

$\chi^2_{count} > \chi^2_{table}$  =  $H_0$  is rejected,  $H_1$  is accepted

**Gonad Maturity Level (GML).** GML was determined by visual observation of the gonadal morphology. Furthermore, the observed characteristics are adjusted to the characteristics of the level of maturity.

**Size at first maturity (Lm).** The value of Lm can be estimated by the Soerman-Karber formula proposed by Udupa (1986), as follows:

$$m = xk + \frac{d}{2} \left( X \sum P_i \right)$$
$$M = \text{antilog} \left( m \pm 1,96 \sqrt{x^2 \sum \frac{p_i \cdot q_i}{n_i - 1}} \right)$$

Where:

$m$  - logarithm of the length class first maturity;

$d$  - difference in the logarithm of the increase in the median length;

$k$  - number of length classes;

$xk$  - logarithm of the median length, where the fish is 100% at gonadal maturity (or where  $p_i = 1$ );

$p_i$  - proportion of mature fish in the  $i^{\text{th}}$  length class, related to the number of fish in the length interval  $i$ ;

$n_i$  - number of fish in the  $i^{\text{th}}$  class of length;

$q_i = 1 - p_i$ ;

$M$  - length of fish at first maturity equal to the anti-log  $m$  (if  $\alpha = 0.05$ , then the confidence interval of  $m$  is 95%).

**First caught size (Lc).** The size of Lc is estimated by the method of Sparre & Venema (1999):

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

The Lc value is obtained by plotting the cumulative frequency percentage of fish caught with a standard length, where the intersection point between the 50% cumulative frequency curve is the length of 50% of the catch. The Lc value can be calculated through the formula (Sparre et al 1989):

$$Lc = \frac{-a}{b}$$

**Catch Per Unit Effort (CPUE).** Catch data and fishing effort obtained are then tabulated to determine CPUE. The fishing effort can be in the form of operating days or months of operation, the number of fishing trips or the number of fleets conducting fishing operations. In this study the fishing effort (effort) used is the number of trips. The formula that can be used to determine the CPUE value is as follows (Noiija et al 2014):

$$CPUE = \frac{Catch_i}{Effort_i}$$

Where:

CPUE<sub>i</sub> - catch per unit of fishing effort in year i (tonnes/unit);

Catch<sub>i</sub> - catch in year i (tons);

Effort<sub>i</sub> - fishing effort in year i (trip).

## Results and discussion

**Length frequency distribution of *K. pelamis*.** Based on the results of observations of 1022 samples of *K. pelamis*, length frequency distribution data was obtained, with the shortest size being 28.5 cm and the longest being 77.3 cm. The distribution of fish length during the observation is presented in Figure 2.

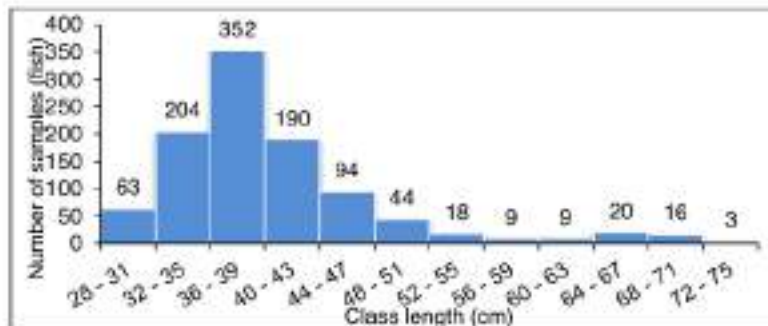


Figure 2. Long frequency distribution of *Katsuwonus pelamis*.

Overall, the mode of the sample was found in the class of 36–39.9 cm, due to the use of Fish Aggregating Devices (FADs) which causes the capture of many specimens with small or immature gonads.

**Length-weight relationship in *K. pelamis*.** The relationship between length and weight obtained is presented in Figure 3, according to the characteristics of the fish growth pattern.

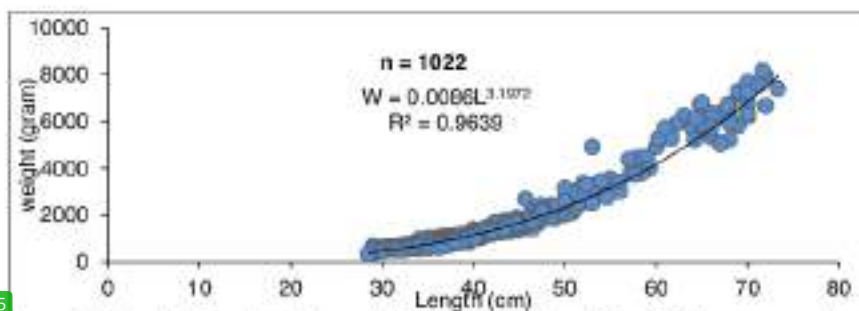


Figure 3. The relationship between the length and weight of *Katsuwonus pelamis*.

From the length-weight relationship it resulted that the length-weight relationship of *K. pelamis* is  $W = 0.0086L^{3.1972}$ , with a value of  $b = 3.1972$ . Then from a t test performed on the value of b, at a 95% confidence interval, it resulted  $t_{count} > t_{table}$  ( $t_{count} = 10.1975$ ;  $t_{table} = 1.962$ ), which means that the increase rates in length and weight were significantly different or the increase in length is not proportional to the increase in weight. The value  $b = 3.1972$  it showed a positive allometric growth pattern, where the weight gain is faster than the increase in length.

Calculation of the growth pattern of *K. pelamis* using the  $t_{count} = 0.05$  at a 95% confidence interval ( $\alpha=0.05$ ) showed that by producing a coefficient of determination (R) of 0.9818 shows a correlation coefficient (r) close to 1. This also shows that the increase in length will affect weight gain by showing that the correlation or relationship between length and fish weight is close and positive.

**Sex ratio of *K. pelamis*.** The observed sample of 100 *K. pelamis*, of which 51 male fish (51%) and 49 female fish (49%), had a sex ratio of 1:1. According to Senen et al (2011), a balanced sex ratio also indicates that one male fish will fertilize one female fish. The number of female fish is a determinant of the sustainability of a population because during the mating season there will be a high competition, so that the natural mortality of males is higher. The sex ratio of *K. pelamis* is presented in Figure 4.

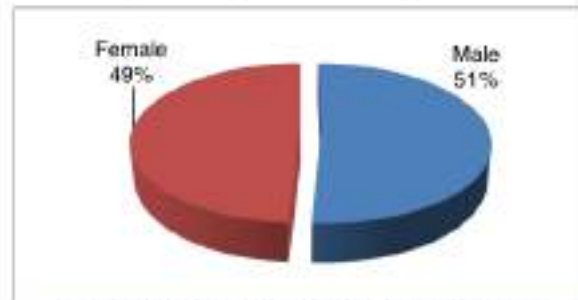


Figure 4. Sex ratio of *Katsuwonus pelamis*.

To find out the accuracy of whether the comparison is balanced or not, it is necessary to calculate the sex ratio using the chi-square test presented in Table 1.

Sex ratio of *Katsuwonus pelamis*

Table 1

| Sex    | N  | $t_{count}$ | $t_{table}$ |
|--------|----|-------------|-------------|
| Male   | 51 | 0.040       | 3.84        |
| Female | 49 |             |             |

The results of the chi-square test are  $t_{count}=0.040$  and  $t_{table}=3.84$ , so that  $t_{count} < t_{table}$  and  $H_0$  is accepted, which means there is no real difference between the male and female populations of *K. pelamis*.

**Gonad maturity level of *K. pelamis*.** The level of maturity of the male gonads can be seen from the size and color of the gonads, while in the female gonads it can be seen from the gonads' size and color and from the presence or absence of eggs in the gonads. The results of gonadal observations can be seen in Table 2.

Percentage of gonad maturity level of *Katsuwonus pelamis*

Table 2

| Sex      | Amount (N) | GML (%) |       |       |      |
|----------|------------|---------|-------|-------|------|
|          |            | I       | II    | III   | IV   |
| Male     | 51         | 41.18   | 31.37 | 19.61 | 7.84 |
| Female   | 49         | 26.53   | 46.94 | 18.37 | 8.16 |
| Combined | 100        | 34      | 39    | 19    | 8    |

For male fish, the number of mature gonads was 27.45% and 72.55% were immature. For female fish, the number of mature gonads was 26.53% and 83.47% were immature. Overall (males and females), the number of mature fish was 27% and 73% were immature. This indicates that more fish are caught before the gonads maturity, suggesting that the fish have not yet had time to spawn, which affects the recruitment in the fishing area.

**Length at first maturity (Lm).** From the observations on the level of gonad maturity and length size distribution against 100 *K. pelamis*, it resulted that the length at first maturity of the gonads was 44.81 cm. By using a 95% confidence level, the confidence interval for size prediction at maturity of gonads is 43.39-46.28 cm. For comparison, the Lm of *K. pelamis* recorded at other locations are presented in Table 3.

Table 3  
Lm of *Katsuwonus pelamis* at other locations

| Lm value (FL)(cm) | Research location                     | Source                  |
|-------------------|---------------------------------------|-------------------------|
| 42.8              | South Seram Island waters             | Manik (2007)            |
| 42.9              | Eastern Indian Ocean Waters           | Jatmiko et al (2015)    |
| 43                | West and South waters of North Maluku | Karman et al (2016)     |
| 43                | West Indian Ocean Waters              | Norungee & Kawol (2011) |
| 46.5              | Bay of Bone, South Sulawesi           | Jamal et al (2011)      |

**Length at first capture (Lc).** Calculation of Lc is done by using data on the length distribution and the number of fish in the purse seine. Based on observation of 226 fish caught by purse seine, it was found that the length of the first caught was 40.12 cm. Lc of *K. pelamis* is presented in Figure 5.

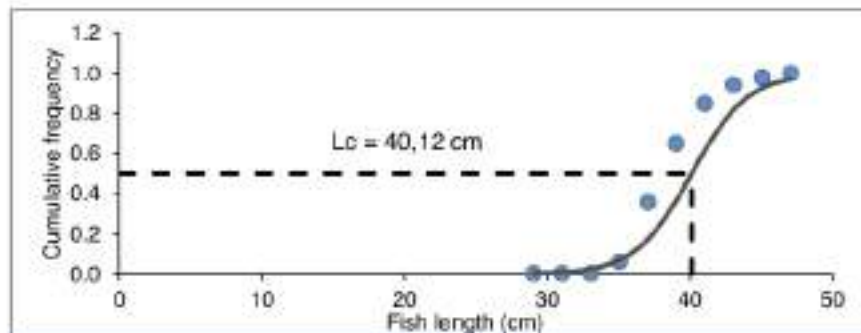


Figure 5. Lc *Katsuwonus pelamis* on a purse seine.

Then a comparison was made between the values of Lm and Lc, showing that for the fish caught by the purse seine has a value  $Lc < Lm$  and it was captured before spawning, which is thought to cause a significant decrease in the population of *K. pelamis*.

**Catch per Unit Effort (CPUE) and Maximum Sustainable Yield (MSY).** Production and fishing efforts of *K. pelamis* in the Banda Sea are carried out using 4 types of fishing gear including handline, troll line, purse seine and pole and line. Production and effort of catching *K. pelamis* can be seen in Table 4.

There are differences in fishing productivity between handline, trolling line, purse seine, and pole and line. It is necessary to standardize productivity, in order to calculate the Fishing Power Index (FPI), which can be seen in Table 5.



Table 4  
Production and catching efforts of *Katsuwonus pelamis* in the Banda Sea

| Year | Production (T) |                |            |                | Total     | Trips        |                |            |                |
|------|----------------|----------------|------------|----------------|-----------|--------------|----------------|------------|----------------|
|      | Purse seiner   | Trolling liner | Hand liner | Pole and liner |           | Purse seiner | Trolling liner | Hand liner | Pole and liner |
| 2008 | 9,186.63       | 9,775.52       | 301.40     | 16,214.11      | 35,477.65 | 23,419       | 427,899        | 123,472    | 157,717        |
| 2009 | 9,137.30       | 9,491.48       | 745.91     | 17,312.00      | 36,686.68 | 23,373       | 392,497        | 248,406    | 123,316        |
| 2010 | 10,253.94      | 13,137.78      | 1,516.36   | 18,689.02      | 43,597.11 | 43,622       | 474,562        | 311,339    | 140,968        |
| 2011 | 11,712.66      | 14,313.94      | 408.27     | 20,519.92      | 46,954.79 | 35,888       | 413,171        | 191,396    | 25,248         |
| 2012 | 12,318.24      | 15,724.01      | 4,232.45   | 16,727.68      | 48,002.38 | 42,027       | 432,897        | 226,447    | 98,277         |
| 2013 | 26,305.18      | 5,484.45       | 5,226.45   | 22,949.42      | 60,965.51 | 52,010       | 536,119        | 186,753    | 217,374        |
| 2014 | 14,806.04      | 15,786.37      | 1,952.18   | 16,740.75      | 53,294.35 | 39,017       | 209,321        | 293,614    | 92,577         |
| 2015 | 14,726.79      | 16,392.38      | 4,127.07   | 19,208.60      | 54,454.84 | 34,787       | 499,933        | 89,352     | 187,803        |
| 2016 | 18,079.96      | 17,311.33      | 4,616.49   | 20,836.71      | 60,044.49 | 41,596       | 497,222        | 204,068    | 165,652        |
| 2017 | 18,272.12      | 18,172.17      | 5,210.66   | 23,064.41      | 64,719.36 | 38,453       | 386,506        | 191,767    | 148,278        |
| 2018 | 20,681.51      | 19,426.73      | 5,158.88   | 24,984.11      | 70,251.22 | 48,078       | 447,850        | 157,874    | 167,308        |

Table 5  
Productivity and Fishing Power Index (FPI) on *Katsuwonus pelamis*

| Year    | Productivity (Ton trip <sup>-1</sup> ) |                |            |                |
|---------|--|----------------|------------|----------------|
|         | Purse seiner                           | Trolling liner | Hand liner | Pole and liner |
| 2008    | 0.3923                                 | 0.0228         | 0.0024     | 0.1028         |
| 2009    | 0.4275                                 | 0.0242         | 0.0030     | 0.1404         |
| 2010    | 0.2351                                 | 0.0277         | 0.0049     | 0.1326         |
| 2011    | 0.3264                                 | 0.0330         | 0.0021     | 0.8127         |
| 2012    | 0.2931                                 | 0.0363         | 0.0187     | 0.1702         |
| 2013    | 0.8218                                 | 0.0121         | 0.0280     | 0.1056         |
| 2014    | 0.3795                                 | 0.0754         | 0.0203     | 0.1809         |
| 2015    | 0.4233                                 | 0.0328         | 0.0484     | 0.1023         |
| 2016    | 0.4347                                 | 0.0348         | 0.0225     | 0.1258         |
| 2017    | 0.4752                                 | 0.0470         | 0.0272     | 0.1555         |
| 2018    | 0.4302                                 | 0.0434         | 0.0327     | 0.1493         |
| Average | 0.4217                                 | 0.0354         | 0.0191     | 0.1980         |
| Index   | Purse seiner                           | Trolling liner | Handliner  | Pole and liner |
| CPUE    | 0.4217                                 | 0.0354         | 0.0191     | 0.1980         |
| FPI     | 1                                      | 0.084          | 0.045      | 0.47           |

Based on Table 5, the purse seine is used as a standard fishing gear, because its productivity is greater than for other fishing gear. Furthermore, the standardization process is performed by multiplying the FPI with the effort numbers (trips) of each fishing gear to get a standard effort. The results that can be seen in Table 6.

Table 6  
Standardization of catching efforts for *Katsuwonus pelamis*

| Year | Purse seiner | Trolling liner | Hand liner | Pole and liner | Standard total effort | CPUE (Ton trip <sup>-1</sup> ) |
|------|--------------|----------------|------------|----------------|-----------------------|--------------------------------|
| 2008 | 23.419       | 35.935         | 5.593      | 74.053         | 139.000               | 0.2552                         |
| 2009 | 21.373       | 32.962         | 11.252     | 57.901         | 123.488               | 0.2971                         |
| 2010 | 43.622       | 39.854         | 14.103     | 66.189         | 163.768               | 0.2662                         |
| 2011 | 35.888       | 36.378         | 8.670      | 11.855         | 92.790                | 0.5060                         |
| 2012 | 42.027       | 36.355         | 10.258     | 46.145         | 134.784               | 0.3636                         |
| 2013 | 32.010       | 45.023         | 8.459      | 102.065        | 187.557               | 0.3250                         |
| 2014 | 39.017       | 17.579         | 13.300     | 43.468         | 113.364               | 0.4701                         |
| 2015 | 34.787       | 41.984         | 3.866      | 88.180         | 168.818               | 0.3226                         |
| 2016 | 41.596       | 41.757         | 9.280      | 77.798         | 170.431               | 0.3570                         |
| 2017 | 38.453       | 32.467         | 8.687      | 69.622         | 149.229               | 0.4337                         |
| 2018 | 48.078       | 37.611         | 7.151      | 78.557         | 171.397               | 0.4099                         |

The CPUE linear equation relationship derived from the effort and yield data (shown in Table 6) shows CPUE yearly fluctuations (Figure 6).

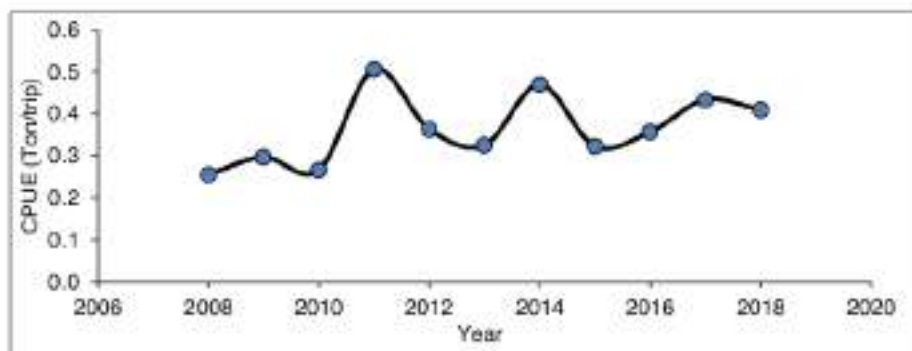


Figure 6. *Katsuwonus pelamis* CPUE fluctuations in the Banda Sea.

From Figure 6, it can be concluded that in 2011 there was the highest CPUE peak. The phenomenon of fluctuations in CPUE is strongly influenced by; (1) the size and number of vessels in operation, (2) type and size of fishing gear, (3) Illegal level, Unreported and Unregulated (IUU) fishing, (4) HR capabilities on board, (5) fishing ground location, (6) the number of fish captures landed (yield), (7) natural conditions during fishing operations and (8) the discipline of the fishing fleet with respect to the specified fishing ground (not fishing in waters that are not in accordance with the permit) (Aritonang et al 2021).

The relationship between CPUE and effort (Figure 7) shows that the estimation parameters for *K. pelamis*, the intercept (a) = 0.5731 and the slope (b) = -0.000001, form a Linear Schaefer equation  $CPUE = -0.000001x + 0.5731$ . This relationship can be interpreted that x supplementary units of effort (trips) per year will reduce the CPUE value by 0.000001 tons per year. The linear equation has a value of  $R^2 = 0.24$ , which means that the effort's influence on the CPUE is of 24%. Thus, the value of  $R^2$  (representing the influence of the variables used in this model) is statistically considered not strong enough.

MSY and EMSY calculation data for *K. pelamis* in the Banda Sea using the Schaefer Linear method are presented in Table 7. The results of biological analysis using the Schaefer Linear model approach can produce an MSY value of 57,837 tonnes with a standard effort/EMSY of 202,473 trips.

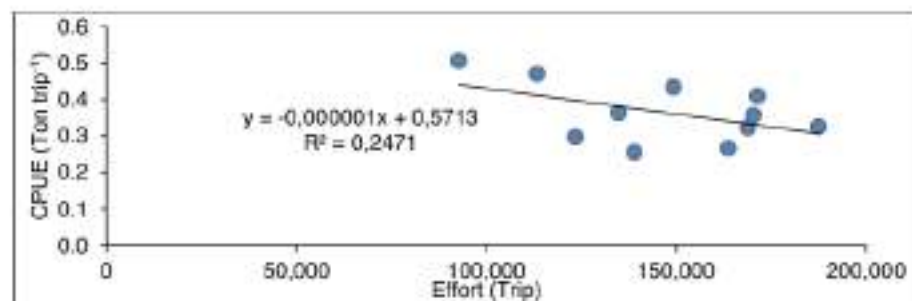


Figure 7. Linear equation of CPUE and effort *Katsuwonus pelamis*.

Based on the calculation of the linear model, biological overfishing has occurred in *K. pelamis* in the Banda Sea, which is indicated by the actual catch having passed MSY. This is evidenced by the actual catch in 2018 which reached 70,251.2 tons, exceeding the Total Allowable Catch (TAC) potential of 80% of the MSY value of 46,269.77 tons. The MSY *K. pelamis* curve can be seen in Figure 8.

Table 7  
MSY and EMSY estimation of *Katsuwonus pelamis* based on Schaefer linear model

| Year                                | Catch number (Ton)   | Total effort standard | CPUE (Schaefer) |
|-------------------------------------|----------------------|-----------------------|-----------------|
| <i>T</i>                            | <i>Y<sub>i</sub></i> | <i>X</i>              | <i>Y</i>        |
| 2008                                | 35.477.7             | 139.000               | 0.2552          |
| 2009                                | 36.686.7             | 123.488               | 0.2971          |
| 2010                                | 43.597.1             | 163.768               | 0.2662          |
| 2011                                | 46.954.8             | 92.790                | 0.5060          |
| 2012                                | 49.002.4             | 134.784               | 0.3636          |
| 2013                                | 60.965.5             | 187.557               | 0.3250          |
| 2014                                | 53.294.3             | 113.364               | 0.4701          |
| 2015                                | 54.454.8             | 168.818               | 0.3226          |
| 2016                                | 60.844.5             | 170.431               | 0.3570          |
| 2017                                | 64.719.4             | 149.229               | 0.4337          |
| 2018                                | 70.251.2             | 171.397               | 0.4099          |
| Amount                              | 576.248.3662         | 1.614.628             | 4.0064          |
| Average value                       | 52.386.22            | 146.784               | 0.3642          |
| Intercept a                         |                      |                       | 0.57131         |
| Slope b                             |                      |                       | -0.000001       |
| MSY Schaefer; $-a^2/4b$             |                      |                       | 57,837          |
| E MSY Schaefer: $-a/2b$             |                      |                       | 202,473         |
| Total Allowable Catch (TAC) 80% MSY |                      |                       | 46,269.77       |

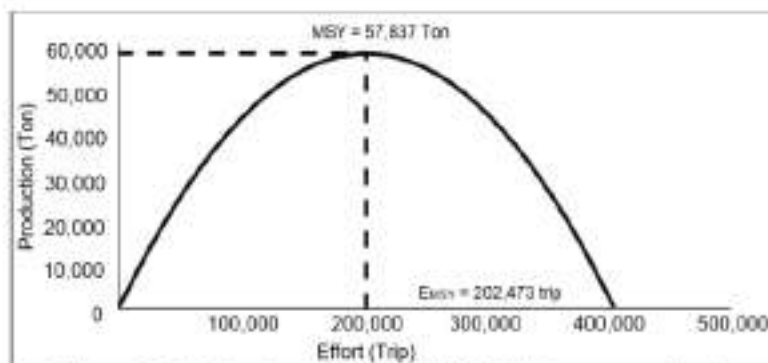


Figure 8. Stock balance curve (MSY) for *Katsuwonus pelamis*.

**Conclusions.** Biological aspects of *K. pelamis* in the Banda Sea show a positive allometric growth pattern. *K. pelamis* risks to be caught before spawning ( $L_c < L_m$ ), resulting in an imbalance in natural stocks, since the fish caught have not yet spawned, therefore the recruitment can be disrupted. *K. pelamis* fisheries increase their production, with a low level of gear selectivity, so that there is a need for regulation of fishing gear and supervision. *K. pelamis* resources exploitation exceeds the maximum point of sustainable production and [13](#) so the MEY, so that the profit decreases, as shown by the actual effort and production values.

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

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Received: 16 March 2023. Accepted: 19 May 2023. Published online: 03 June 2023.

Authors:

Maman Hermawan, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, AUP Street No.1, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: mhermawan60@gmail.com

Jerry Hutajulu, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, AUP Street No.1, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: jerryhutajulu15@gmail.com

Syarif Syamsuddin, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, AUP Street No.1, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: bgershark007@gmail.com

Yusrizal, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, AUP Street No.1, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: buyung\_trc@yahoo.com

Danu Sudrajat, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, AUP Street No.1, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: sudrajatwrb1@gmail.com

Aman Saputra, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, AUP Street No.1, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: amansaputra@yahoo.com

Erick Nugraha, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, AUP Street No.1, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: nugraha\_eric1@yahoo.co.id

Ratna Suharti, Jakarta Technical University of Fisheries, Faculty of Aquatic Resources Management, AUP Street No.1, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: r\_suharti@yahoo.com

Firman Setiawan, Jakarta Technical University of Fisheries, Faculty of Aquatic Resources Management, AUP Street No.1, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: firmansetiawan001@gmail.com

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How to cite this article:

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