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Eni Kovacs <ek.bioflux@gmail.com>
Kepada: erick nugraha

Sen, 30 Jan jam 23.51

Dear Dr. Nugraha,

Thank you for your interest in publishing with us.

The editorial team will assess your manuscript and I will get back to you as soon as possible with the result.

> Tampilkan pesan asli

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Kind regards,
Eniko Kovacs
AACL Bioflux Editor

Status of the *Thunnus albacares* fishery in the Fisheries Management Area (FMA) 714, Maluku Sea - Indonesia

[1]Ratna Suharti, [1]Mira Maulita, [1]Firman Setiawan, [1]Basuki Rachmad, [1]Dadan Zulkifli, [2]Mantani Sayuri, [3]Maman Hermawan, [3]Erick Nugraha

[1]Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, South Jakarta, Indonesia; [2]Department of Ships Navigation, Marine Technical College, Hyogo, Japan; [3]Faculty of Fishing Technology, Jakarta Technical University of Fisheries, South Jakarta, Indonesia; Corresponding author: E. Nugraha, nugraha_eriq1@yahoo.co.id

Abstract. The Banda Sea is a potential fishing area for large pelagic fish, especially tuna. Exploitation of this resource is carried out by various forms of fishing activities, including purse seine, pole and line, longline tuna, and handline tuna. Based on the results of a study on tuna stocks by the Western and Central Pacific Fisheries Commission (WCPFC) in 2012, it was reported that yellowfin stocks were not overfished and overfished, while bigeye tuna were overfished and overfished. In addition, the utilization of fish resources in FMA RI 714 is still dominated by small-scale fishermen using vessels <5 GT. Based on the magnitude of the potential and the condition of the available large pelagic fish resources. So, it is necessary to study the status of large pelagic fisheries, especially tuna in the Maluku region. This study aims to examine the biological and fisheries aspects of tuna. The research was carried out from 4 March to 25 May 2021 in the Maluku Sea. This study used a survey method, namely by observing in the field the observed fish samples. Determination of the location and fishing gear is carried out by purposive sampling, namely collecting data deliberately according to the desired conditions. While the determination of respondents was carried out by accidental sampling, namely the determination of tuna fishermen by accident. The results showed that the growth pattern of *T. albacares* was isometric. The size of the first caught in the purse seine for *T. albacares* was 39.09 cmFL. The use of tuna in FMA RI 714 shows that the actual production and fishing effort for tuna shows that its utilization has not reached the maximum sustainable potential value and economically, tuna fishing has not yet reached the maximum profit value so that its utilization can still be increased.

Keywords: Yellowfin tuna, Banda Sea, Gonad Maturity Level (GML), Sex ratio, Size at first maturity (Lm).

Introduction

The Banda Sea is the waters of the Eastern Indonesia Region which is included in the waters of the West Pacific Ocean and is bordered by the Indian Ocean (Firdaus 2018). The Banda Sea has also become a very potential tuna fishing area in Maluku Province (Satrioajie et al 2018; Tangke et al 2011). Exploitation of tuna resources is carried out in various forms of fishing activities, including purse seiner, pole and liner, longliner and tuna handliner (Tauda et al 2021; Khan et al 2018; Widodo & Nugraha 2009).

Tuna resources are spread throughout almost all Indonesian waters, from western Indonesian waters (Indian Ocean) to Eastern Indonesia (Banda Sea and North Irian Jaya) (Chodrijah & Nugraha 2013). The waters of Eastern Indonesia are known as centers for the production of tuna and skipjack which are commonly called tuna in Indonesia (Manurung 2016). One of the waters that has become a potential fishing area for large pelagic fish in eastern Indonesia is the Banda Sea (Hidayat et al 2014).

Based on the results of a study of tuna stocks by the Western and Central Pacific Fisheries Commission (WCPFC) in 2012 it was reported that stocks of yellowfin tuna (*Thunnus albacares*) were not overfished and overfished, while bigeye tuna (*Thunnus obesus*) had experienced overfished and overfished (Post & Squires 2020; Hare et al 2020; Widodo et al 2015). Utilization of fish resources in WPP 714 is still dominated by small-scale fishermen using vessels <5GT (JICA 2010; Adam 2016) based on the large potential and condition of available large pelagic fish resources, so it is necessary to study the status of large pelagic fisheries, especially tuna in the Maluku region.

This study aims to examine several aspects of *T. albacares* including; a) biological aspects including length-weight relationship; b) Assessing aspects of the T. albacares fishery including production trends, fishing effort, fishing grounds, fishing season, fishing gear and CPUE; and c) Assessing efforts to manage and utilize tuna which includes calculating catch rate, Maximum Sustainable Yield, Maximum Economic Yield, and Total Allowable Catches of *T. albacares* in the Maluku region.

Material and Methods

The research was conducted for 90 days, from March 4 to May 25, 2021, in the Maluku Sea which focused on fishing ports with high tuna landing potential. Data collection was carried out at several sampling points as shown in Figure 1.

Figure 1. Map of Research Locations

Tools and Materials

The tools and materials used in this study are as follows: Rulers, tape measure, digital scales, cameras, stationery, identification labels, and some samples of tuna.

Methods of data collection

In this study a survey method was used, namely by observing in the field the observed fish samples. Determination of the location and fishing gear was carried out by purposive sampling, namely collecting data deliberately according to the desired conditions (Tongco 2007). Meanwhile, the determination of respondents was carried out by accidental sampling, namely the accidental determination of tuna fishermen (Siburian et al 2020).

Data collection for *T. albacares* sampling was carried out using the simple random sampling method, namely simple random sampling by taking samples to measure the length and weight of fish as much as 10% of the total catch (Mous et al 1995). Secondary data needed is in the form of periodic data (time series) of catches and fishing effort for 5 to 10 years from the relevant agencies.

Data Collection

Primary data collection was carried out by direct observation and measurement (Hardani et al 2020) of landed *T. albacares*. The data collected included: fork length, total weight, sex, and GML. Secondary data needed is in the form of periodic data (time series) of catches and fishing effort for the last 10 years obtained from the Maritime Affairs and Fisheries Service of Maluku Province.

Data analysis
Length Frequency Distribution

How to obtain the frequency distribution by determining the class interval, class mean, and frequency in each long group. The long frequency distribution that has been determined with the same class intervals can then be formed in a diagram to see the results of the long frequency distribution.

Length-Weight Relationship

The model used to estimate the relationship between length and weight is an exponential relationship with the following equation (Nugraha et al 2020; Effendie 1979):

$$W = aL^b$$

Description:
W : Fish weight (grams)
L : Standard/fork length fish (cm)
a : The constant number or intercept that is sought from the regression calculation
b : The exponent or tangential angle

To determine the values of a and b a linear regression analysis is needed or by taking the logarithm of the formula above. The linear equation becomes:

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

Then a simple linear equation can be made (Agustian et al 2021):

$$Y = a + bX$$

Where: Y =
X = independent
a' = Antilog Intercept
b = Slope

$$b = \frac{\sum Xi\ Yi}{\sum Xi^2}$$

Where:

$$\Sigma Xi^2 = \Sigma X^2 - \frac{(\sum X)^2}{N}$$

$$\Sigma Yi^2 = \Sigma Y^2 - \frac{(\sum Y)^2}{N}$$

$$\Sigma Xi\ Yi = \Sigma XY - \frac{(\sum X)(\sum Y)}{N}$$

Once the value of b is known, the value of a can be calculated in the following way:

$$a' = \bar{Y} - b\dot{X}$$

$$a = e^{a'}$$

If you pay more attention, then the probability that the price b that appears is b<3, b =3, and b>3. According to Effendie (1979) each value of b can be interpreted as follows:

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

According to Effendie (1979), the T_{test} is used to determine whether the value of b obtained is significantly different from 3 or not, using the following method:

$$\Sigma d^2yx = \Sigma Yi^2 - \frac{(\Sigma XiYi)^2}{\Sigma Xi^2}$$

$$S^2yx = \frac{\Sigma d^2yx}{(N-2)}$$

$$S^2b = \Sigma Xi^2$$

$$Sb = \sqrt{S^2b}$$

$$t = \left|\frac{3-b}{Sb}\right|$$

Where: b = exponential value obtained in the analysis

Sb = standard deviation of Y value

t_{table} Test at 95% confidence level (n-2db)

a. If $t_{count} > t_{table}$ then it is significantly different

b. If $t_{count} < t_{table}$ then it is not significantly different

Correlation coefficient (r) to see the close relationship between length and weight is obtained from:

$$r^2 = \frac{(\Sigma XiYi)^2}{(\Sigma Xi^2)(\Sigma Yi^2)}$$

$$r = \sqrt{r^2}$$

Where:

r = correlation coefficient, is an abstract measure of the degree of closeness of the relationship between variables x and y ($-1 \leq r \leq 1$)

r = 1, meaning that there is a close and positive relationship

r = -1, means that there is a close and negative relationship

r = 0, meaning that there is no close relationship

Sex Ratio

Comparison of the sexes of biota is done by visual observation of a number of male and female individuals obtained as samples at the study site. The sex ratio is known by using the formula:

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

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

Where: X = number of male fish

Y = number of female fish

After the sex ratio in percentage is obtained, to find out whether there is a significant difference between the ratio of male and female individuals, it is carried out through testing and the 'X^2' (chi square) test with the formula according to Effendie (1979):

$$X^2 = \frac{(fo-fh)^2}{fh}$$

Where:

X^2 = chi square

f_0 = observed biota

f_h = expected biota frequency

X^2 value obtained from this calculation, then the value is compared with the value of X^2 table with a confidence level of 95% and degrees of freedom (db) = 1 with the hypothesis:

H_0 = there is no significant difference between the number of male and female biota

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

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

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

Gonads Maturity Level (GML)

The gonads maturity level of the was determined by visual observation of the morphology of the gonads. Furthermore, the observed characteristics are adjusted to the GML criteria listed in Table 1.

Table 1

Classification of Gonad Maturity Levels (GML) (Karman et al 2013)

Level	Gonadal state	Description
I	Immature	Gonads are elongated, small almost transparent
II	Maturing	Gonads are enlarged, pink-beige in color, the eggs cannot be seen with visual
III	Mature	Gonads are creamy-yellow in color, eggs can be seen with visual
IV	Ripe	Eggs are enlarged and clear yellow in color, can come out with a little pressure on the stomach
V	Spent	Gonads are smaller, red in color and have lots of blood vessels

Size at first maturity (Lm)

Size at first maturity (Lm) can be estimated by the Soerman-Karber formula proposed by (Udupa 1986) as follows:

$$m = xk + \frac{d}{2} - (X \sum Pi)$$

$$M = \text{antilog}\,(m \pm 1{,}96\sqrt{x^2 \Sigma \frac{pi * qi}{n_i - 1}})$$

Note:

- m = logarithm of class length at first maturity
- d = logarithmic difference of the mean length increase
- k = number of length classes
- *xk* = logarithm of the median length where fish are 100% gonadal mature (or $p_i = 1$)
- p_i = proportion of gonadal mature fish in length class i with the number of fish in the i-th length interval
- n_i = $1 - p_i$
- q_i = the number of fish in the i-th class length
- M = the length of the fish when the gonads first mature is anti-log m, if $\propto = 0.05$, then the confidence interval is 95% of m

Length at first caught (Lc)

The length of fish first caught (Lc) was estimated by the method (Sparre & Venema 1998):

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

The value of Lc was obtained by plotting the percentage of the cumulative frequency of fish caught with the standard length, where the intersection point between the 50% cumulative frequency curve is the length when 50% of the fish are caught (Diningrum et al 2019). The value of Lc can be calculated using the formula:

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

Catch Per Unit Effort (CPUE)

Catch data and fishing effort obtained, then tabulated to determine the value of 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 carrying out 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 (Imron et al 2022):

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

Where:
CPUEi = catch per unit of fishing effort in year i (tons/unit)
Catchi = catch in year i (tons)
EffortI = fishing effort in year i (trip)

Standardization of Fishing Gear

According to Ardelia et al (2018), standardization is done by finding the Fishing Power Index (FPI) value of each fishing gear. The fishing gear used as standard has an FPI value equal to one, while the FPI value for other fishing gear is obtained from the CPUE of the other fishing gear divided by the CPUE of the standard fishing gear. The formula for calculating FPI is as follows:

$$RFP_i = \frac{Ci/Ei}{Cs/Es}$$

Description:

RFP_i	=	catching power factor of fishing units which will be standardized in year i
C_i	=	the number of catches of the type of fishing unit that will be standardized in year-i
C_s	=	the number of catches of the type of fishing unit that will be standardized in year-i
E_i	=	the amount of effort of catching the type of fishing unit which will be standardized in the i-year
E_s	=	total effort of catching the type of fishing unit which is standardized in the i-year

After obtaining the RFPi value, the standardized fishing effort is calculated using the formula:

$$\text{Effort standar} = FPI_i \times \text{Effort}$$

Production Surplus Model

The purpose of using the Surplus Production Surplus Model is to determine the level of effort optimum, which is an effort that can produce a maximum sustainable catch without affecting long-term stock productivity which we usually call Maximum Sustainable Yield (Sari & Nurainun 2022).

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

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

Description:
Y(i) = catch in year i, I = 1, 2, ...n
f(i) = fishing effort in year i, I = 1, 2, ...n

Determining the value of a (intercept) and b (slope) requires linear regression f(i) to Y(i)/f(i). After the a and b values are obtained, the optimum effort (f_{MSY}) and Maximum Sustainable Yield (MSY) can be calculated by the formula:

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

Next, to find out the level of utilization of fish resources by percentizing the number of catches in a certain year with the maximum Sustainable Yield (MSY):

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

Information:
Ci = number of fish caught in year i
MSY = Maximum Sustainable Yield

RESULTS AND DISCUSSION

Distribution of T. albacares Length Frequency

Based on observations of 339 samples of *T. albacares*, the distribution of frequency distribution data with the shortest length was 31 cm and the longest is 126 cm. The long frequency distribution is presented in Figure 2.

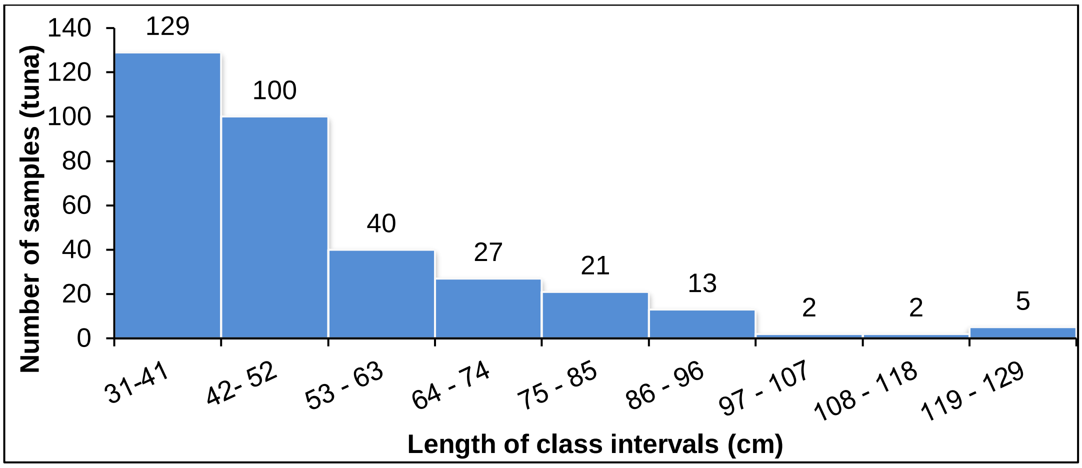

Figure 2. Length frequency distribution of *T. albacares*

Mode of measurement for *T. albacares* samples was found at class intervals of 31-41 cm. This happens because many small fish are caught by trolling liner and purse seiner and because many fishermen make a "Tuna loin" process on board so that measurements cannot be taken.

The relationship between length and weight of T. albacares

The relationship between length and weight obtained is presented on the graph according to the characteristics of the fish growth pattern as shown in Figure 3.

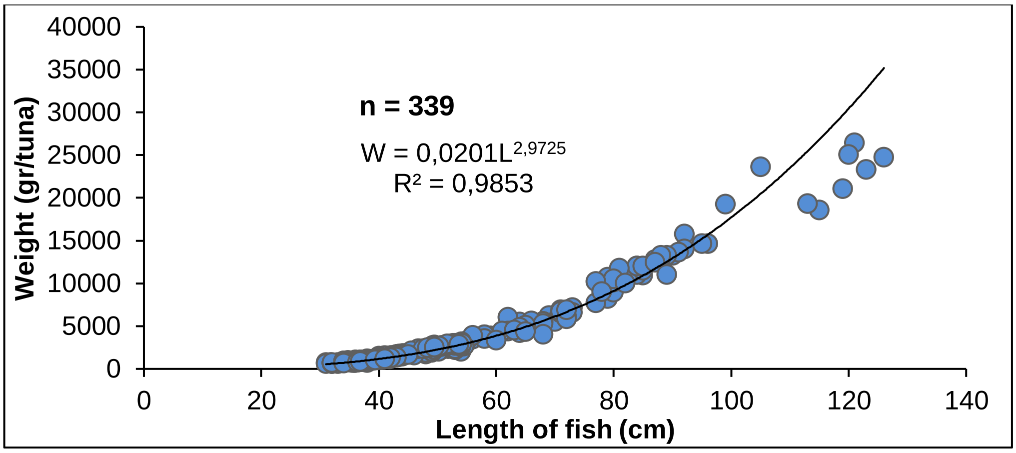

Figure 3. Length-weight relationship of *T. albacares.*

From the results of the analysis of the length-weight relationship in Figure 20, the relationship between the length and weight of the species *T. albacares* is $W = 0.0201L^{2.9725}$, with a value of $b = 2.9725$. Then a t_{-test} was carried out on the value of b at a 95% confidence interval, obtained $t_{count} < t_{table}$ ($t_{count} = 1.393$; $t_{table} = 1.967$), then H_0 is accepted, which means that the increase in length and weight is not significantly different, so that it can be said that the increase in length is proportional to the increase in weight (isometric).

From the results of the t_{test}, it is necessary to carry out further calculations to obtain a new length-weight relationship equation by substituting the values of $\bar{Y}$ and $\bar{X}$ using $\bar{Y} = a' - 3\bar{X}$. In order to obtain a new equation for the relationship between the weight of *T. albacares*, namely $W = 0.018055L^3$. Calculation of the growth pattern was carried out using the t $_{test}$ (t_{count} = 0.05) at a 95% confidence interval (α 0.05) showing that by producing a coefficient of determination (R) of 0.9928 this shows a correlation coefficient (r) close to 1. This also shows that the increase in length affects weight gain by showing that the correlation or relationship between length and fish weight is close and positive.

Length at first capture (Lc)

Calculation of the size of the first catch on *T. albacares* was carried out using data on the length and number of fish caught in purse seine catches. Based on observations of the 70 caught, the Lc was 39.55 cm as can be seen in Figure 4.

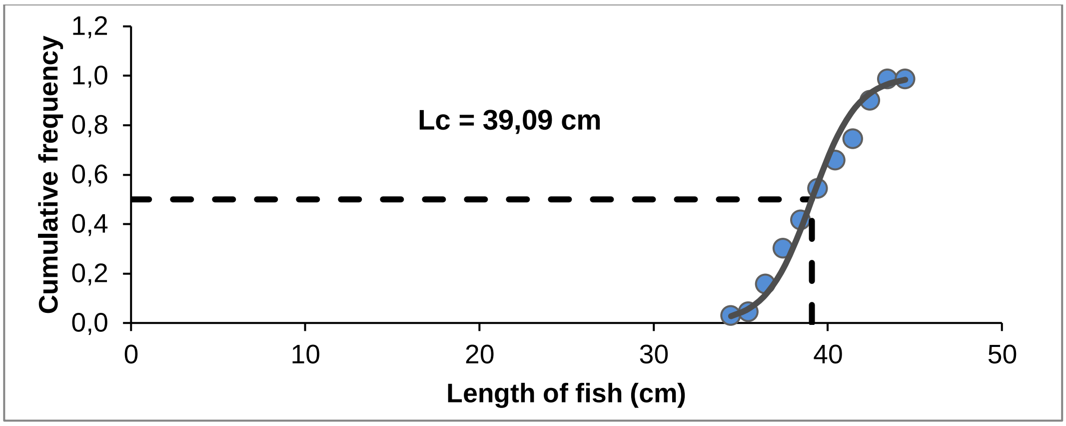

Figure 4. Lc *T. albacares* on purse seine.

Fishing Ground

The dominant fishing grounds for fishermen in the province of Maluku are in the Banda Sea (FMA RI 714) where these waters are areas that are usually approached by *T. albacares* due to environmental factors, food availability and are spawning and egg-laying areas. To get the maximum catch, the right season is needed when catching where the highest catch occurs when it enters the East season or is called the harvest season. The harvest season is from October to December, the lean season is from May to July, the western season is from December to January and the transition season is from April to May. The catches obtained depend on the season, currents and wind which are obstacles for fishermen to go to sea and make catches.

Stock status in Fishery Management Area - Republic of Indonesia (FMA-RI 714) CPUE and MSY T. albacares

In table 2 below it can be seen the production data and fishing effort of *T. albacares* in FMA RI-714 by handliner, troll liner, purse seiner, and the pole and liner.

Table 2

FMA RI-714 Production and Fishing Effort

Year	Production (tons)					Trip			
	Purse seiner	Trolling liner	Hand liner	Pole and liner	Total	Purse seiner	Trolling liner	Hand liner	Pole and liner
2008	3,868.71	3,813.07	39.29	3,127.51	10,848.57	23,419	427,899	201	8,546
2009	3,997.51	4,961.22	1,500.39	3,754.16	14,213,28	21,373	392,497	248,406	9,457
2010	3,982.52	1,335.69	993.14	2,752.55	9,063.90	43,622	474,562	311,339	8,429
2011	4,710.08	9,739.77	2,424.13	6,639.34	23,513.32	35,888	433,171	191,396	7,641
2012	5,169.07	14,869.32	1,017.65	4,037.61	25,093.65	42,027	432,897	226,447	10,617
2013	19,288.48	10,298.59	3,125.72	3,964.70	36,677.49	32,010	484,526	186,753	10,646
2014	6,094.66	3,863.20	4,381.17	4,397.88	18,736.91	39,017	141,506	293,614	7,797
2015	4,505.92	381.21	2,587.83	5,494.17	12,969.12	34,787	247,776	85,352	8,922

2016	10,159.34	879.72	3,675.05	7,856.27	22,570.37	41,596	291,150	204,868	8,657
2017	13,102.44	1,476.79	5,140.45	8,321.75	28,041.43	38,453	226,620	191,767	8,125
2018	13,661.33	2,145.53	6,076.82	12,722.25	34,605.93	48,078	255,188	157,874	8,698

There are differences in fishing productivity between handliner, troll liner, purse seiner, and pole and liner, it is necessary to standardize productivity, to obtain the Fishing Power Index (FPI) as can be seen in the table 3.

Table 3

Productivity and Fishing Power Index (FPI) in *T. albacares*

Year	Productivity (Tons/trip)			
	Purse seine	Trolling line	Hand line	Pole and line
2008	0.1652	0.0089	0.1955	0.3660
2009	0.1870	0.0126	0.0060	0.3970
2010	0.0913	0.0028	0.0032	0.3265
2011	0.1312	0.0225	0.0127	0.8689
2012	0.1230	0.0343	0.0045	0.3803
2013	0.6026	0.0213	0.0167	0.3724
2014	0.1562	0.0273	0.0149	0.5641
2015	0.1295	0.0015	0.0303	0.6158
2016	0.2442	0.0030	0.0179	0.9075
2017	0.3407	0.0065	0.0268	1.0242
2018	0.2841	0.0084	0.0385	1.4627
Average	0.2232	0.0136	0.0334	0.6623
CPUE	0.2232	0.0136	0.0334	0.6623
FPI	0.3370	0.0204	0.0504	1

Based on Table 3, the huhate is used as standard fishing gear, because its productivity islarger than other fishing gear. Furthermore, the standardization process by multiplying the FPI with each fishing gear to get a standard effort with the results can be seen in Table 4.

Table 4

Standardization of *T. albacares* Catching Efforts

Year	Purse seiner	Trolling liner	Hand liner	Pole and liner	Total Effort Standard	CPUE (Ton/trip)
2008	7,892	8,765	10	8,546	25,213	0.4303
2009	7,203	8,040	12,515	9,457	37,215	0.3819
2010	14,701	9,721	15,686	8,429	48,538	0.1867
2011	12,094	8,873	9,643	7,641	38,251	0.6147
2012	14,163	8,868	11,409	10,617	45,057	0.5569
2013	10,787	9,925	9,409	10,646	40,768	0.8997
2014	13,149	2,899	14,793	7,797	38,637	0.4849
2015	11,723	5,076	4,300	8,922	30,022	0.4320
2016	14,018	5,964	10,322	8,657	38,961	0.5793
2017	12,959	4,642	9,662	8,125	35,388	0.7924
2018	16,202	5,227	7,954	8,698	38,082	0.9087

The effort and yield data shown in Table 3 will produce CPUE fluctuations every year as shown in Figure 5.

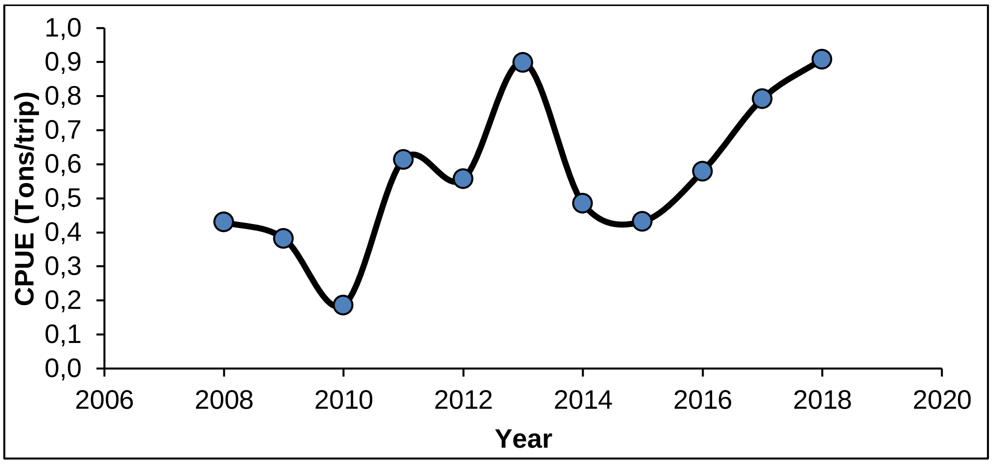

Figure 5. *T. albacares* CPUE fluctuation in FMA-RI 714

From Figure 5 it can be concluded that 2013 was the highest CPUE point. Even though the CPUE decreased from 2014 to 2015, the conditions did not disturb the sustainability of tuna fishing activities in FMA-RI 714.

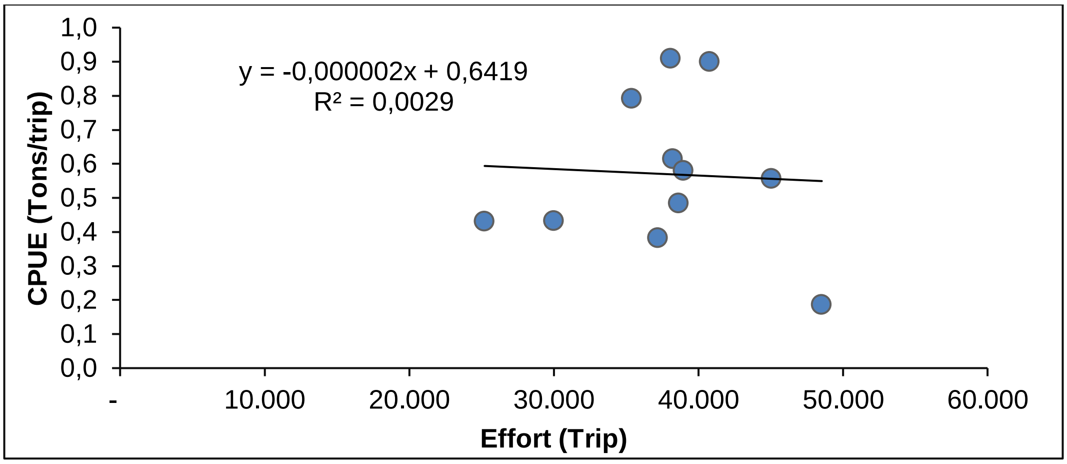

Figure 6. Linear equations of CPUE and Effort *T. albacares*

The relationship between CPUE and effort in Figure 6 shows that the value of the estimation parameter for Tuna is obtained by intercept (a) = 0.6419 and slope (b) = -0.000002 so as to form an equation Linear Schaefer CPUE = -0.000002x + 0.6419. This relationship can be interpreted that by catching x units per year, it will reduce the CPUE value by 0.000002 tons per year. The conditions described in the linear equation produce a value of R^2 = 0.0029 which means that around 0.29% the influence of the variables used, namely effort and yield. Thus, the R^2 value is statistically considered not strong enough to represent the influence of the variables used in this model because the closer the R^2 value is to 100%, the stronger the variable influence.

MSY and EMSY calculation data for *T. albacares* in FMA-RI 714 using the Schaefer Linear method are presented in Table 5. The results of biological analysis using the Schaefer Linear model approach can produce an MSY value of 54,027 tons with a standard effort/EMSY of 168,332 trips.

Table 5

MSY and EMSY *T. albacares* Based on Schaefer Linear Model Calculations

Year	Number of Catches (Tons)	Total Standard Effort	CPUE (Schaefer)
I	Yi	X	Y
2008	10,848.5	25,213	0.4303
2009	14,213.2	37,215	0.3819
2010	9,063.9	48,538	0.1867
2011	23,513.3	38,251	0.6147
2012	25,093.6	45,057	0.5569
2013	36,677.5	40,768	0.8997
2014	18,736.9	38,637	0.4849
2015	12,969.1	30,022	0.4320
2016	22,570.3	38,961	0.5793
2017	28,041.4	35,388	0.7924
2018	34,605.9	38,082	0.9087
Total	236,333.9	416,131	6.2676
Average	21,484.9	37,830	0.5697
	Intercept a		0.6419
	Slope b		-0.000002
	MSY Schaefer: -a^2/4b		54,027
	EMSY Schaefer: -a/2b		168,332
	Total Allowable Catch (TAC) 80% MSY		43,221.80

Based on linear model calculations, biological saturation yields have not occurred in *T. albacares* in FMA RI-714 which is indicated with actual catches that are not close to their sustainable potential (MSY). This is evidenced by the actual catch in 2018 which reached 34,605.9 tonnes, not yet exceeding the potential TAC of 80% of the MSY value of 43,221.80 tonnes. The sustainable potential curve (MSY) of *T. albacares* can be seen in Figure 7.

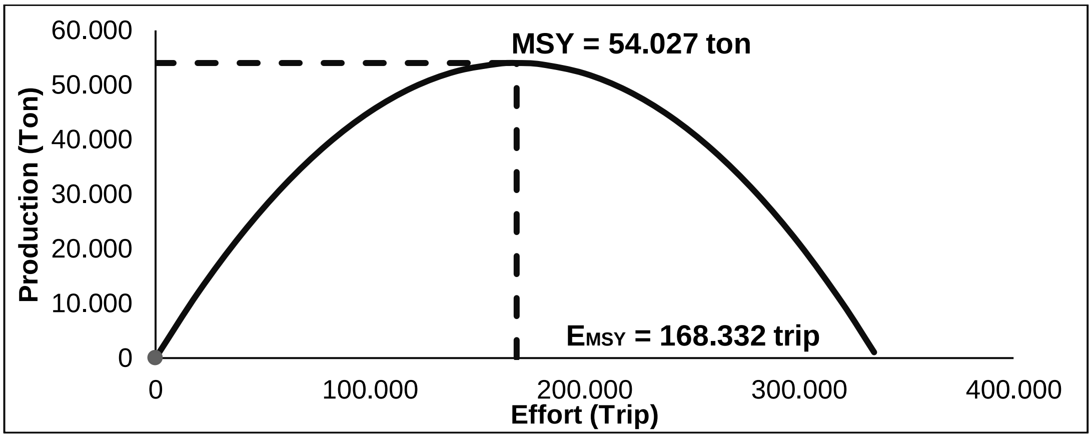

Figure 7. Stock Equilibrium Curve (MSY) of *T. albacares* in FMA RI-714

Conclusion

1) The biological aspects of *T. albacares* in Maluku waters show that the growth pattern of tuna is isometric.
2) The fishery aspect of *T. albacares* is in a condition where production continues to increase with a low level of fishing gear selectivity. So that there is a need for regulation of fishing gear and its supervision.

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Authors:
Ratna Suharti, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: r_suharti@yahoo.com

Mira Maulita, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: maulita.stp@gmail.com
Firman Setiawan, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: firmansetiawan001@gmail.com
Dadan Zulkifli, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: belfyludaputri@gmail.com
Basuki Rachmad, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: basukibye248@gmail.com
Maman Hermawan, Faculty of Fishing Technology, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: mhermawan60@gmail.com
Mantani Sayuri, Department of Ships Navigation, Japan Agency of Maritime Education and Training for Seafarers, Marine Technical College, Ashiya City 659-0026, Hyogo, Japan, e-mail: mantani-s6ea@jmets.ac.jp
Erick Nugraha, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: nugraha_eriq1@yahoo.co.id

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Hereby I would like to submit the manuscript entitled “Conditions and characteristics of coral reefs in Gusung Batu Lampe, Muara Badak, Kutai Kartanegara, Indonesia” to Aquaculture, Aquarium, Conservation & Legislation - International Journal of the Bioflux Society.

This manuscript was not submitted or published to any other journal. The authors declare that the manuscript is an original paper and contain no plagiarized text. All authors declare that they are not currently affiliated or sponsored by any organization with a direct economic interest in subject of the article. My co-authors have all contributed to this manuscript and approve this submission.

Author,

Ratna Suharti   Mira Maulita   Maman Hermawan

Firman Setiawan   Basuki Rachmad   Dadan Zulkifli

Mantani Sayuri   Erick Nugraha (Corresponding author)

Date: January 29, 2023

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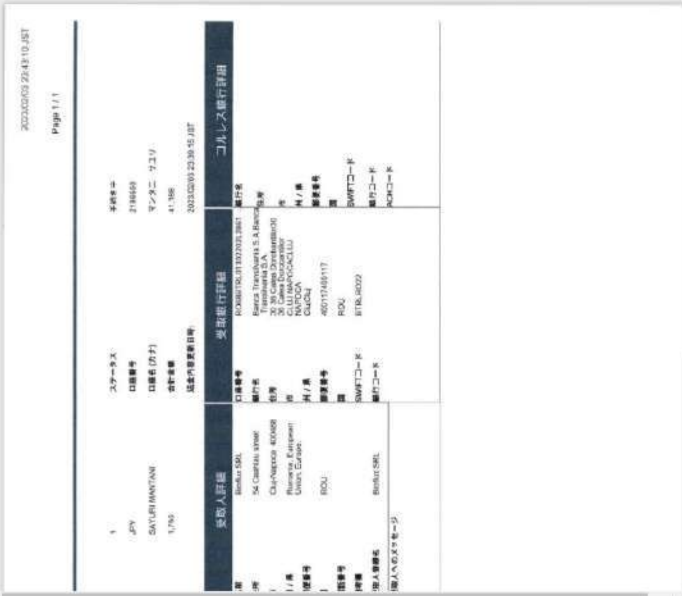

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Thank you.

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Status of the *Thunnus albacares* fishery in the Fisheries Management Area (FMA) 714, Maluku Sea, Indonesia

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Banda Sea?

[1]Ratna Suharti, [1]Mira Maulita, [1]Firman Setiawan, [1]Basuki Rachmad, [1]Dadan Zulkifli, [2]Mantani Sayuri, [3]Maman Hermawan, [3]Erick Nugraha

[1] Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, South Jakarta, Indonesia; [2] Department of Ships Navigation, Marine Technical College, Hyogo, Japan; [3] Faculty of Fishing Technology, Jakarta Technical University of Fisheries, South Jakarta, Indonesia~~;~~ . Corresponding author: E. Nugraha, nugraha_eriq1@yahoo.co.id

Abstract. The Banda Sea is a potential fishing area for large pelagic fish, especially tuna. Exploitation of this resource is carried out by various forms of fishing activities, including purse seine, pole and line, longline tuna, and handline tuna. Based on the results of a study on tuna stocks by the Western and Central Pacific Fisheries Commission (WCPFC) in 2012, it was reported that yellowfin stocks were not overfished ~~and overfished~~, while bigeye tuna were overfished ~~and overfished~~. In addition, the utilization of fish resources in FMA RI 714 is still dominated by small-scale fishermen using vessels <5 GT. Based on the magnitude of the potential and the condition of the available large pelagic fish resources. ~~So~~Thus, it is necessary to study the status of large pelagic fisheries, especially tuna in the Maluku region. This study ~~aims~~ aimed to examine the biological ~~and fisheries~~ aspects of tuna and the fisheries management. The research was carried out from 4 March to 25 May 2021 in the Maluku Sea. This study used a survey method, namely by observing in the field the observed fish samples. Determination of the location and fishing gear ~~is~~ was carried out by purposive sampling, ~~, namely collecting data deliberately according to the desired conditions. w~~While the determination of respondents was carried out by accidental sampling~~, namely the determination of tuna fishermen by accident~~. The results showed that the growth pattern of *T. albacares* was isometric. The size of the first caught in the purse seine for *T. albacares* was 39.09 cm FL. ~~The use of tuna i~~In FMA RI 714, ~~shows that~~ the actual production and tuna fishing effort ~~for tuna~~ shows that its utilization ~~has~~ did not reach~~ed~~ the maximum sustainable ~~potential value~~level and economically, tuna fishing ~~has~~ did not yet reach~~ed~~ the maximum profit value so that its utilization can still be increased.

Key Words: yellowfin tuna, banda sea, gonad maturity level (~~gml~~GML), sex ratio.

Commented [WU2]: Not appropriate for the abstract.

Commented [WU3]: Must be rephrased!

Commented [WU4]: Full name when first mentioned in the text.

Commented [A5]: FL = fork length?

Introduction. The Banda Sea is ~~the waters of~~located in the Eastern Indonesia Region ~~which~~ and is included in the waters of the West Pacific Ocean ~~and is~~ , being bordered by the Indian Ocean (Firdaus 2018). The Banda Sea has also become a ~~very~~ potential tuna fishing area in Maluku Province (Satrioajie et al 2018; Tangke et al 2011). Exploitation of tuna resources is carried out in various forms of fishing activities, including purse seiner, pole and liner, longliner and tuna handliner (Tauda et al 2021; Khan et al 2018; Widodo & Nugraha 2009). Tuna resources are spread throughout almost all Indonesian waters, from western Indonesian waters (Indian Ocean) to Eastern Indonesia (Banda Sea and North Irian Jaya) (Chodrijah & Nugraha 2013). The waters of Eastern Indonesia are known as ~~centers~~ sources for the production of tuna and skipjack, which are commonly called tuna in Indonesia (Manurung 2016). Banda Sea ~~One of the waters that has become a potentia~~is~~l~~ a fishing ~~area~~ ground for large pelagic fish in eastern Indonesia ~~is the Banda Sea~~ (Hidayat et al 2014).

Based on the results of a study of tuna stocks by the Western and Central Pacific Fisheries Commission (WCPFC) in 2012, it was reported that stocks of yellowfin tuna (*Thunnus albacares*) were not ~~overfished and~~ overfished, while bigeye tuna (*Thunnus obesus*) ~~had~~ experienced ~~overfished and overfished~~ overfishing (Post & Squires 2020; Hare et al 2020; Widodo et al 2015). ~~Utilization~~ The utilization of fish resources in WPP 714 is still dominated by small-scale fishermen using vessels <5GT (JICA 2010; Adam 2016), ~~based~~ due ~~on~~ to the ~~large potential and condition of available~~ availability of large pelagic fish resources~~,~~. ~~so it is necessary to study~~Therefore, monitoring the status of large pelagic fisheries in the Maluku region, especially those targeting tuna~~, in the Maluku region~~ is required.

This study ~~aims~~ aimed to examine several aspects of *T. albacares* ~~including;~~ : a) biological aspects, including length-weight relationship~~;~~ , b) ~~Assessing aspects of the~~ *T. albacares* ~~fishery~~exploitation characteristics, including production trends, fishing effort, fishing grounds, fishing season, fishing gear and CPUE~~;~~ and c) ~~Assessing efforts to~~ management ~~and utilize~~of tuna resources, which includes calculating the catch rate, Maximum Sustainable Yield, Maximum Economic Yield, and Total Allowable Catches of *T. albacares* in the Maluku region.

Material and Method

The research was conducted for 90 days, from March 4 to May 25, 2021, in the Maluku Sea, by ~~which focused~~ focusing on fishing ports with high tuna landing potential. Data collection was carried out at several sampling points, as shown in Figure 1.

Commented [WU6]: Banda Sea, Maluku Island?

Figure 1. Map of research locations.

Tools and materials. The tools and materials used in this study are as follows: rulers, tape measure, digital scales, cameras, stationery, identification labels, and some samples of tuna.

Methods of data collection. In this study, ~~a~~ the applied survey method was ~~used, namely by observing in~~ the field ~~the~~ observ~~ed fish samples~~ationed. Determination of the location and fishing gear was carried out by purposive sampling, namely collecting data deliberately according to the desired conditions (Tongco 2007). Meanwhile, the determination of respondents was carried out by accidental sampling, namely the accidental determination of tuna fishermen (Siburian et al 2020). Data collection for *T. albacares* sampling was carried out using the simple random sampling method, ~~namely simple random sampling~~ by ~~taking samples to measure~~ measuring the specimens' length and weight of ~~fish as much as~~ 10% of the total catch (Mous et al 1995). Secondary data ~~needed is in the form of periodic data~~are ~~(~~time series~~)~~ of catches and fishing effort for 5 to 10 years, from the relevant agencies.

Data collection. Primary data collection was carried out by direct observation and measurement (Hardani et al 2020) of landed *T. albacares*. The data collected included:

fork length, total weight, sex, and GML. Secondary data needed is in the form of periodic data (time series) of catches and fishing effort for the last 10 years obtained from the Maritime Affairs and Fisheries Service of Maluku Province.

Data analysis

Length frequency distribution. T~~How to obtain t~~he frequency distribution was obtained by determining the class interval, class mean, and frequency in each ~~long~~ length group, then the results were presented in a diagram. ~~The long frequency distribution that has been determined with the same class intervals can then be formed in a diagram to see the results of the long frequency distribution.~~

Length-weight relationship. The model used to estimate the relationship between length and weight is ~~an~~ exponential, ~~relationship with~~ using the following equation (Nugraha et al 2020; Effendie 1979):

$$W = aL^b$$

Where:
W-fish weight (g);
L-standard/fork length fish (cm);
a-the constant number or intercept, that is sought from the regression calculation;
b-the exponent or tangential angle.

To determine the values of a and b, a linear regression analysis, based on ~~is needed or by taking~~ the logarithm of the formula above. The linear equation becomes:

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

Then a simple linear equation can be made (Agustian et al 2021):

$$Y = a + bX$$

Where: Y =
X-Ln L~~independent~~;
a'-antilog intercept;
b-slope.

$$b = \frac{\Sigma Xi\, Yi}{\Sigma Xi^2}$$

Where:

$$\Sigma Xi^2 = \Sigma X^2 - \frac{(\Sigma X)^2}{N}$$

$$\Sigma Yi^2 = \Sigma Y^2 - \frac{(\Sigma Y)^2}{N}$$

$$\Sigma Xi\, Yi = \Sigma XY - \frac{(\Sigma X)(\Sigma Y)}{N}$$

Once the value of b is known, the value of a can be calculated in the following way:

$$a' = \bar{Y} - b\dot{x}$$

$$a = e^{a'}$$

~~If you pay more attention, then the probability that the price b that appears is b<3, b =3, and b>3.~~ According to Effendie (1979) each value of b can be interpreted as follows:

1) If b<3, then the increase in length is faster than the increase in weight ~~or~~; it is called a negative allometric.
2) If b>3, then the weight gain is faster than the increase in length ~~or~~ ; it is called a positive allometric.
3) If b=3, then the increase in length and weight gain are balanced ~~or~~; it is called isometric allometry.

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Commented [A8]: ? Y = Ln W

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According to Effendie (1979), the T-test is used to determine whether the value of b obtained is significantly different from 3 or not, using the following method:

$$\Sigma d^2yx = \Sigma Yi^2 - \frac{(\Sigma XiYi)^2}{\Sigma Xi^2}$$

$$S^2yx = \frac{\Sigma d^2yx}{(N-2)}$$

$$S^2b = \Sigma Xi^2$$

$$Sb = \sqrt{S^2b}$$

$$t = \left|\frac{3-b}{Sb}\right|$$

Where:
b = exponential value obtained in the analysis
Sb = standard deviation of Y value
t_{table} Test at 95% confidence level (n-2db)
a. If $t_{count} > t_{table}$ then it is significantly different
b. If $t_{count} < t_{table}$ then it is not significantly different

The c~~C~~orrelation coefficient (r), describing the ~~to see the close~~ strength of the relationship between length and weight is obtained from the following formula (….et al…..):

$$r^2 = \frac{(\Sigma XiYi)^2}{(\Sigma Xi^2)(\Sigma Yi^2)}$$

$$r = \sqrt{r^2}$$

Where:
r^2-the coefficient of determination
r-the correlation coefficient, is an abstract measure of the ~~degree of closeness~~ strength of the relationship between variables x and y ($-1 \leq r \leq 1$);
r-1, ~~meaning~~ means that there is a ~~close~~ strong and positive relationship;
r--1, means that there is a ~~close~~ strong and negative relationship;
r-0, ~~meaning~~ means that there is no ~~close~~ relationship.

Sex ratio. Comparison of the sexes of biota is done by visual observation of a number of male and female individuals obtained as samples at the study site. The sex ratio is known by using the formula:

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

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

Where: X = number of male fish
Y = number of female fish

After the sex ratio in percentage is obtained, to find out whether there is a significant difference between the ratio of male and female individuals, it is carried out through testing and the 'X^2' (chi square) test with the formula according to Effendie (1979):

$$X^2 = \frac{(fo-fh)^2}{fh}$$

Where:
X^2 = chi square
f_0 = observed biota
f_h = expected biota frequency

X^2 value obtained from this calculation, then the value is compared with the value of X^2 table with a confidence level of 95% and degrees of freedom (db) = 1 with the hypothesis:
H_0 = there is no significant difference between the number of male and female biota
H_1 = there is a significant difference between the number of male and female biota
If, $X^2_{count} < X^2_{table}$ = H_0 is accepted, H_1 is rejected

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

Gonads Maturity Level (GML). The gonads maturity level of the was determined by visual observation of the morphology of the gonads. Furthermore, the observed characteristics are adjusted to the GML criteria listed in Table 1.

Table 1

Classification of Gonad Maturity Levels (GML) (Karman et al 2013)

Level	Gonadal state	Description
I	Immature	Gonads are elongated, small almost transparent
II	Maturing	Gonads are enlarged, pink-beige in color, the eggs cannot be seen with visual
III	Mature	Gonads are creamy-yellow in color, eggs can be seen with visual
IV	Ripe	Eggs are enlarged and clear yellow in color, can come out with a little pressure on the stomach
V	Spent	Gonads are smaller, red in color and have lots of blood vessels

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

$$m = xk + \frac{d}{2} - (X \sum Pi)$$

$$M = \text{antilog}\ (m \pm 1{,}96 \sqrt{x^2 \Sigma \frac{pi*qi}{n_i - 1}})$$

Note:

m = logarithm of class length at first maturity
d = logarithmic difference of the mean length increase
k = number of length classes
xk = logarithm of the median length where fish are 100% gonadal mature (or p_i = 1)
p_i = proportion of gonadal mature fish in length class i with the number of fish in the i-th length interval
n_i = 1 – p_i
q_i = the number of fish in the i-th class length
M = the length of the fish when the gonads first mature is anti-log m, if ∝ = 0.05, then the confidence interval is 95% of m

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

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

The value of Lc was obtained by plotting the percentage of the cumulative frequency of fish caught with the standard length, where the intersection point between the 50% cumulative frequency curve is the length when 50% of the fish are caught (Diningrum et al 2019). The value of Lc can be calculated using the formula (...):

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

Catch Per Unit Effort (CPUE)~~–~~. Catch data and fishing effort were obtained, then tabulated to determine the value of CPUE. The fishing effort can be expressed as ~~in~~ the ~~form~~ number of operating days or months ~~of operation~~, the number of fishing trips or the number of fleets carrying out fishing operations. In this study the fishing effort (effort)

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used is expressed as the number of trips. The formula that can be used to determine the CPUE value is as follows (Imron et al 2022):

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

Where:
$CPUE_i$-catch per unit of fishing effort ~~in year~~for the period i (tons~~/unit~~ trip^{-1});
$Catch_i$-catch for the period i ~~in year i~~ (tons);
~~EffortI~~ $Effort_i$-fishing effort for the period i ~~in year i~~ (trip).

Standardization of fishing gear. According to Ardelia et al (2018), standardization is done by finding the Fishing Power Index (FPI) value of each fishing gear. The fishing gear used as standard has an FPI value equal to one, while the FPI value for other fishing gear is obtained from the CPUE of the other fishing gear divided by the CPUE of the standard fishing gear. The Gulland formula for calculating FPI is as follows:

$$RFP_i = \frac{Ci/Ei}{Cs/Es}$$

~~Description~~Where:

RFP_i	=	~~catching~~ relative fishing power factor of the i^{th} fishing unit~~s which will be standardized in year i~~
C_i	=	the number of catches ~~of the type~~ of the i^{th} fishing unit ~~that will be standardized in year i~~
C_s	=	the standard number of catches of the ~~type of~~ fishing unit type~~that will be standardized in year i~~
E_i	=	the ~~amount of~~ effort of catching with the i^{th}~~type of~~ fishing unit ~~which will be standardized in the i year~~
E_s	=	~~total~~ the standard effort of catching with the ~~type of~~ fishing unit type~~which is standardized in the i year~~

After obtaining the RFP_i value, the standardized fishing effort is calculated using the formula:

$$\text{standard eEffort}~~\text{ffort standar}~~ = \sum(FPI_{ii} \times effort_i E)~~\text{ffort}~~$$

Production surplus model. The purpose of using the ~~Surplus~~ Production Surplus Model is to determine the level of ~~effort optimum~~optimal effort, ~~which is an effort that can produce~~corresponding to a maximum sustainable catch without affecting long-term stock productivity which we usually call Maximum Sustainable Yield (Sari & Nurainun 2022).

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

$$CPUE = \frac{Y}{f} = \frac{Y(i)}{f(i)}, i = 1, 2, ... n$$

~~Description~~Where:
Y(i) - catch for the period i~~in year i~~, I = 1, 2, ...n;
f(i) - fishing effort for the period i~~in year i, I = 1, 2, ...n~~.

Determining the value of a (intercept) and b (slope) requires linear regression of f(i) to Y(i)/f(i). After the a and b values are obtained, the optimum effort (f_{MSY}) and Maximum Sustainable Yield (MSY) can be calculated by the formula:

$$f_{MSY} = -\frac{a}{2b} \text{ ~~dan~~and } MSY = -\frac{a^2}{4b}$$

~~Next, to find out t~~The level of utilization of fish resources ~~by percentizing~~is ~~the~~ a fraction~~number of catches in a certain year~~ of~~with~~ the maximum Sustainable Yield (MSY):

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

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Ci - number of fish caught in year ~~i~~I;
MSY - maximum sustainable yield.

Results and discussion

Distribution of T. albacares length frequency. Based on observations of 339 samples of *T. albacares*, ~~the distribution of frequency distribution data with~~ the shortest length was 31 cm and the longest is 126 cm. The length~~ong~~ frequency distribution is presented in Figure 2.

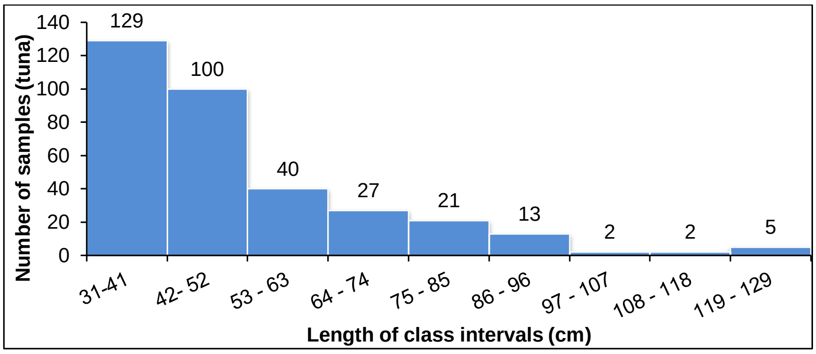

Figure 2. Length frequency distribution of *Thunnus albacares.*

~~Mode of measurement for *T. albacares* samples was found at~~The modal class intervals ~~was~~of 31-41 cm~~. This happens because~~: many small fish are caught by trolling liner and purse seiner. ~~and because many fishermen make a "Tuna loin" process on board so that measurements cannot be taken.~~

The relationship between length and weight of T. albacares. The relationship between length and weight ~~obtained~~ is presented on the graph, according to the characteristics of the fish growth pattern, as shown in Figure 3.

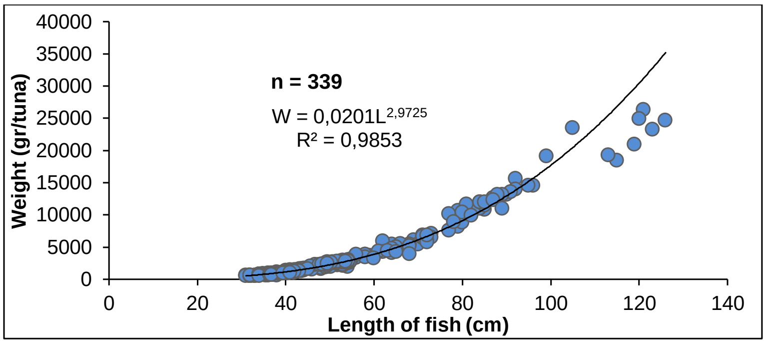

Figure 3. Length-weight relationship of *Thunnus albacares.*

From the results of the analysis of the length-weight relationship of the species *T. albacares*~~in Figure 20~~, the ~~relationship between the length and~~ following equation was ~~weight of the species *T. albacares* is~~ determined: $W = 0.0201\ L^{2.9725}$, with a value of b = 2.9725. Then a t_{test} was carried out on the value of b at a 95% confidence interval and~~,~~ obtained $t_{count} < t_{table}$ ($t_{count} = -1.393$; $t_{table} = -1.967$), ~~then~~ therefore H_0 ~~is~~ was accepted, which means that the increase rates in length and weight ~~is~~ are not significantly different,

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so that it can be said that the increase in length is proportional to the increase in weight (isometric).

From the results of the t_{test}, it is necessary to carry out further calculations to obtain a new *T. albacares* length-weight relationship equation, by substituting the values of $\bar{y}$ and $\bar{X}$ using $\bar{y}$ = a' - 3$\bar{X}$~~.~~ , ~~In order to obtain a new equation for the relationship between the weight of *T. albacares*,~~ namely W = 0.018055 L^3. Calculation of the growth pattern was carried out using the t_{test} (t_{count} = 0.05), at a 95% confidence interval (α = 0.05), ~~showing that by~~ producing a coefficient of determination (R^2) of 0.9928 ~~this shows~~and a correlation coefficient (r) close to 1. This ~~also~~ shows that ~~the~~ an increase in the length affects the weight gain, ~~by show~~meaning that the correlation or relationship between length and fish weight is ~~close~~ strong and positive.

Length at first capture (Lc). Calculation of the size of the first catch ~~on~~ of *T. albacares* was carried out using data on the length and number of fish caught in purse seine catches. Based on the observation~~s~~ of the 70 caught specimens, the Lc was 39.55 cm as it can be seen in Figure 4.

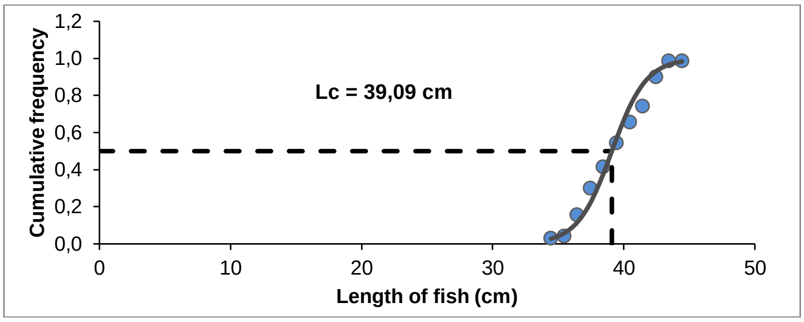

Figure 4. Length at first capture of *Thunnus albacares* on purse seine.

Fishing ground. The dominant fishing grounds for fishermen in the province of Maluku are located in the Banda Sea (FMA RI 714). ~~where~~ T~~t~~hese ~~waters are~~ areas ~~that~~ are usually approached by *T. albacares* due to environmental factors, food availability and they are also spawning and egg-laying areas. The~~o get the maximum catch, the right season is needed when catching where the~~ highest catch occurs ~~when it enters~~at the beginning of the East season, also ~~or is~~ called the harvest season~~. The harvest season is~~, from October to December. T~~, t~~he lean season is from May to July, the western season is from December to January and the transition season is from April to May. The catches obtained depend on the season, currents and wind, which ~~are~~ might be obstacles for ~~fishermen to~~ going to sea and succeeding to make catches.

Stock status in Fishery Management Area - Republic of Indonesia (FMA-RI 714)
CPUE and MSY T. albacares. In table 2 below it can be seen the production data and fishing effort of *T. albacares* in FMA RI-714 by hand liner, troll liner, purse seiner, and the pole and liner.

Table 2

FMA RI-714 production and fishing effort

Year	Production (tons)					Trip			
	Purse seiner	Trolling liner	Hand liner	Pole and liner	Total	Purse seiner	Trolling liner	Hand liner	Pole and liner
2008	3,868.71	3,813.07	39.29	3,127.51	10,848.57	23,419	427,899	201	8,546
2009	3,997.51	4,961.22	1,500.39	3,754.16	14,213,28	21,373	392,497	248,406	9,457

2010	3,982.52	1,335.69	993.14	2,752.55	9,063.90	43,622	474,562	311,339	8,429
2011	4,710.08	9,739.77	2,424.13	6,639.34	23,513.32	35,888	433,171	191,396	7,641
2012	5,169.07	14,869.32	1,017.65	4,037.61	25,093.65	42,027	432,897	226,447	10,617
2013	19,288.48	10,298.59	3,125.72	3,964.70	36,677.49	32,010	484,526	186,753	10,646
2014	6,094.66	3,863.20	4,381.17	4,397.88	18,736.91	39,017	141,506	293,614	7,797
2015	4,505.92	381.21	2,587.83	5,494.17	12,969.12	34,787	247,776	85,352	8,922
2016	10,159.34	879.72	3,675.05	7,856.27	22,570.37	41,596	291,150	204,868	8,657
2017	13,102.44	1,476.79	5,140.45	8,321.75	28,041.43	38,453	226,620	191,767	8,125
2018	13,661.33	2,145.53	6,076.82	12,722.25	34,605.93	48,078	255,188	157,874	8,698

There are differences in fishing productivity between hand liner, troll liner, purse seiner, and pole and liner, it is necessary to standardize productivity, to obtain the Fishing Power Index (FPI) as can be seen in the table 3.

Table 3

Productivity and fishing power index (FPI) in *Thunnus albacares*

Year	Productivity (Tons/ trip^{-1})			
	Purse seine	Trolling line	Hand line	Pole and line
2008	0.1652	0.0089	0.1955	0.3660
2009	0.1870	0.0126	0.0060	0.3970
2010	0.0913	0.0028	0.0032	0.3265
2011	0.1312	0.0225	0.0127	0.8689
2012	0.1230	0.0343	0.0045	0.3803
2013	0.6026	0.0213	0.0167	0.3724
2014	0.1562	0.0273	0.0149	0.5641
2015	0.1295	0.0015	0.0303	0.6158
2016	0.2442	0.0030	0.0179	0.9075
2017	0.3407	0.0065	0.0268	1.0242
2018	0.2841	0.0084	0.0385	1.4627
Average	0.2232	0.0136	0.0334	0.6623
CPUE	0.2232	0.0136	0.0334	0.6623
FPI	0.3370	0.0204	0.0504	1

Based on Table 3, the huhate is used as standard fishing gear, because its productivity is larger than other fishing gear. Furthermore, the standardization process, resulting from the multiplication of theby multiplying the FPI with each the number of fishing gears–, to get aproduces the standard effort values with the results can be seenpresented in Table 4.

Table 4

Standardization of *ThunnusT. albacares* catching efforts

Year	Purse seiner	Trolling liner	Hand liner	Pole and liner	Total Effort Standard	CPUE (Ton/trip)
2008	7,892	8,765	10	8,546	25,213	0.4303
2009	7,203	8,040	12,515	9,457	37,215	0.3819
2010	14,701	9,721	15,686	8,429	48,538	0.1867
2011	12,094	8,873	9,643	7,641	38,251	0.6147

2012	14,163	8,868	11,409	10,617	45,057	0.5569
2013	10,787	9,925	9,409	10,646	40,768	0.8997
2014	13,149	2,899	14,793	7,797	38,637	0.4849
2015	11,723	5,076	4,300	8,922	30,022	0.4320
2016	14,018	5,964	10,322	8,657	38,961	0.5793
2017	12,959	4,642	9,662	8,125	35,388	0.7924
2018	16,202	5,227	7,954	8,698	38,082	0.9087

The effort and yield data shown in Table 3 will produce CPUE fluctuations every year as shown in Figure 5.

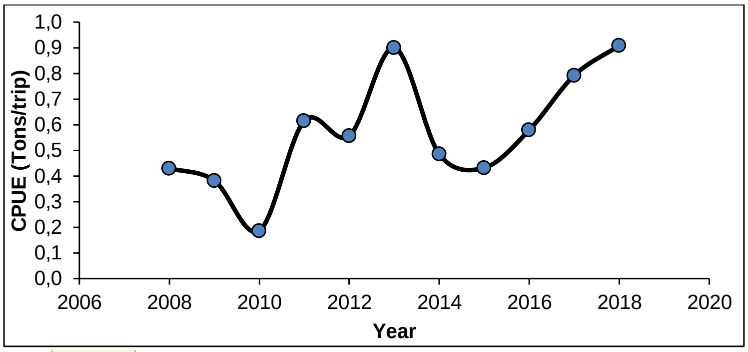

Figure 5. *Thunnus ~~T.~~ albacares* CPUE fluctuation in FMA-RI 714.

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From Figure 5 it can be concluded that 2013 was the highest CPUE point. Even though the CPUE decreased from 2014 to 2015, the conditions did not disturb the sustainability of tuna fishing activities in FMA-RI 714.

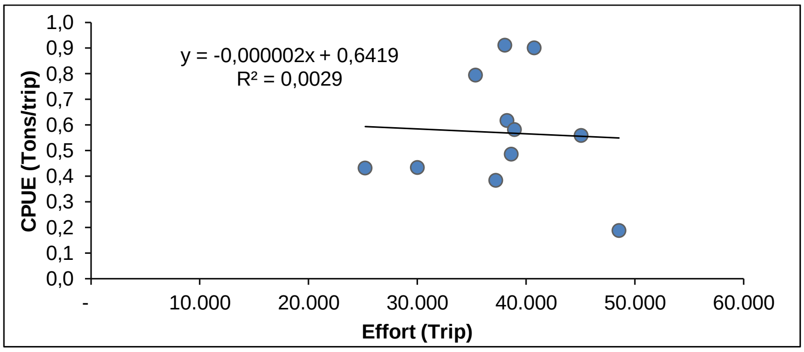

Figure 6. Linear equations of CPUE and effort *Thunnus ~~T.~~ albacares*.

The relationship between CPUE and effort in Figure 6 shows that the value of the estimation parameter for ~~Tuna~~ tuna fish is obtained by an intercept (a) = 0.6419 and a slope (b) = -0.000002 so as to form ~~an~~ the ~~equation Linear~~ Schaefer linear equation CPUE = -0.000002x + 0.6419. This relationship can be interpreted that by catching x units per year, it will reduce the CPUE value by 0.000002 tons per year. The conditions described in the linear equation produce a value of R^2 = 0.0029 which means that around 0.29% the CPUE is influenced ~~of the variables used, namely~~ by the effort ~~and yield~~. Thus, the R^2 value ~~is statistically considered not strong enough to represent~~ indicate that the influence of the variables used in this model ~~because the closer the R² value is to 100%, the stronger the variable influence~~is not strong.

Maximum Sustainable Yield (MSY) and Economic Maximum Sustainable Yield (EMSY) calculation data for *T. albacares* in FMA-RI 714 using the Schaefer Linear method are presented in Table 5. The results of biological analysis using the Schaefer Linear model approach can produce an MSY value of 54,027 tons with a standard effort/EMSY of 168,332 trips.

Table 5

MSY and EMSY *Thunnus ~~T.~~ albacares* Based on Schaefer linear model calculations

Year	Number of Catches (Tons)	Total Standard Effort	CPUE (Schaefer)
I	Yi	X	Y
2008	10,848.5	25,213	0.4303
2009	14,213.2	37,215	0.3819
2010	9,063.9	48,538	0.1867
2011	23,513.3	38,251	0.6147
2012	25,093.6	45,057	0.5569
2013	36,677.5	40,768	0.8997
2014	18,736.9	38,637	0.4849
2015	12,969.1	30,022	0.4320
2016	22,570.3	38,961	0.5793
2017	28,041.4	35,388	0.7924
2018	34,605.9	38,082	0.9087
Total	236,333.9	416,131	6.2676
Average	21,484.9	37,830	0.5697
Intercept a			0.6419
Slope b			-0.000002
MSY Schaefer: -a^2/4b			54,027
EMSY Schaefer: -a/2b			168,332
Total Allowable Catch (TAC) 80% MSY			43,221.80

Based on linear model calculations, biological saturation yields have not occurred in *T. albacares* ~~in~~ from FMA RI-714, which is indicated ~~with~~ by actual catches that are not close to their sustainable potential (MSY). This is evidenced by the actual catch in 2018 which reached 34,605.9 tonnes, not yet exceeding the potential TAC of 80% of the MSY value ~~of~~ (43,221.80 tonnes). The sustainable potential curve (MSY) of *T. albacares* can be seen in Figure 7.

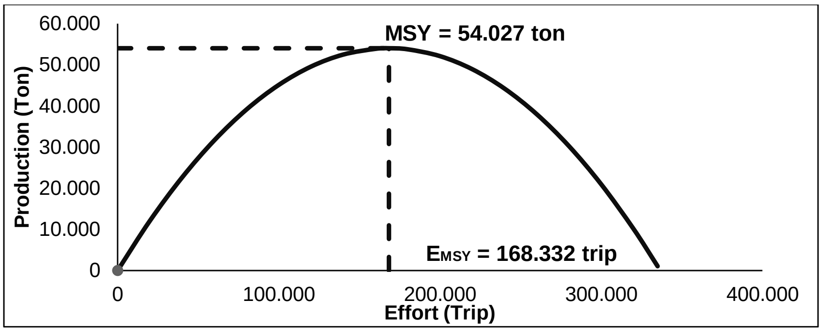

Figure 7. Stock equilibrium curve (MSY) of *Thunnus ~~T.~~ albacares* in FMA RI-714.

Conclusions. The biological aspects of *T. albacares* in Maluku waters show that the growth pattern of tuna is isometric. The ~~fishery aspect of~~exploitation of *T. albacares* is in a condition where production continues to increase with a low level of fishing gear selectivity~~.~~ ~~So~~, therefore ~~that there is a need for regulation~~ regulating ~~of~~ and supervising the fishing gear are required ~~and its supervision~~.

Conflict of interest. The author declares no conflict of interest.

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Authors:
Ratna Suharti, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: r_suharti@yahoo.com
Mira Maulita, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: maulita.stp@gmail.com
Firman Setiawan, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: firmansetiawan001@gmail.com
Dadan Zulkifli, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: belfyludaputri@gmail.com
Basuki Rachmad, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: basukibye248@gmail.com
Maman Hermawan, Faculty of Fishing Technology, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: mhermawan60@gmail.com
Mantani Sayuri, Department of Ships Navigation, Japan Agency of Maritime Education and Training for Seafarers, Marine Technical College, Ashiya City 659-0026, Hyogo, Japan, e-mail: mantani-s6ea@jmets.ac.jp
Erick Nugraha, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: nugraha_eriq1@yahoo.co.id

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← Kembali Arsipkan Pindahkan Hapus Spam •••

erick nugraha <nugraha_eriq1@yahoo.co.id>
Kepada: Eni Kovacs

Kam, 30 Mar jam 19.21

Dear Dr. Eni Kovacs

I send an edited manuscript.

thank you.

Erick Nugraha

› Tampilkan pesan asli

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Status of the *Thunnus albacares* fishery in the Fisheries Management Area (FMA) 714, ~~Maluku~~ Banda Sea, Indonesia

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Banda Sea?

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[1]Ratna Suharti, [1]Mira Maulita, [1]Firman Setiawan, [1]Basuki Rachmad, [1]Dadan Zulkifli, [2]Mantani Sayuri, [3]Maman Hermawan, [3]Erick Nugraha

[1] Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, South Jakarta, Indonesia; [2] Department of Ships Navigation, Marine Technical College, Hyogo, Japan; [3] Faculty of Fishing Technology, Jakarta Technical University of Fisheries, South Jakarta, Indonesia. Corresponding author: E. Nugraha, nugraha_eriq1@yahoo.co.id

Abstract. The Banda Sea is a potential fishing area for large pelagic fish, especially tuna. Exploitation of this resource is carried out by various forms of fishing activities, including purse seine, pole and line, longline tuna, and handline tuna. ~~Based on the results of a study on tuna stocks by the Western and Central Pacific Fisheries Commission (WCPFC) in 2012, it was reported that yellowfin stocks were not overfished, while bigeye tuna were overfished.~~ In addition, the utilization of fish resources in FMA RI 714 is still dominated by small-scale fishermen using vessels <5 GT. Based on the large potential and condition of the available large pelagic fish resources, it is necessary to study the status of large pelagic fisheries, ~~Based on the magnitude of the potential and the condition of the available large pelagic fish resources. Thus, it is necessary to study the status of large pelagic fisheries,~~ especially tuna in the Maluku region. This study aimed to examine the biological aspects of tuna and the fisheries management. The research was carried out from 4 March to 25 May 2021 in the Maluku Sea. This study used a survey method, namely by observing in the field the observed fish samples. Determination of the location and fishing gear was carried out by purposive sampling, while the determination of respondents was carried out by accidental sampling. The results showed that the growth pattern of *Thunnus albacares* was isometric. The size of the first caught in the purse seine for *T. albacares* was 39.09 cm Fork Length. In Fisheries Management Area of Republic Indonesia (FMA RI) 714, the actual production and tuna fishing effort shows that its utilization did not reach the maximum sustainable level and economically, tuna fishing did not yet reach the maximum profit value so that its utilization can still be increased.

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Key Words: yellowfin tuna, banda sea, length of first caught~~gonad maturity level (GML)~~, ~~sex ratio~~CPUE.

Introduction. The Banda Sea is located in the Eastern Indonesia Region and is included in the waters of the West Pacific Ocean, being bordered by the Indian Ocean (Firdaus 2018). The Banda Sea has also become a potential tuna fishing area in Maluku Province (Satrioajie et al 2018; Tangke et al 2011). Exploitation of tuna resources is carried out in various forms of fishing activities, including purse seiner, pole and liner, longliner and tuna handliner (Tauda et al 2021; Khan et al 2018; Widodo & Nugraha 2009). Tuna resources are spread throughout almost all Indonesian waters, from western Indonesian waters (Indian Ocean) to Eastern Indonesia (Banda Sea and North Irian Jaya) (Chodrijah & Nugraha 2013). The waters of Eastern Indonesia are known as sources for the production of tuna and skipjack, which are commonly called tuna in Indonesia (Manurung 2016). Banda Sea is a fishing ground for large pelagic fish in eastern Indonesia (Hidayat et al 2014).

Based on the results of a study of tuna stocks by the Western and Central Pacific Fisheries Commission (WCPFC) in 2012, it was reported that stocks of yellowfin tuna (*Thunnus albacares*) were not overfished, while bigeye tuna (*Thunnus obesus*) experienced overfishing (Post & Squires 2020; Hare et al 2020; Widodo et al 2015). The utilization of fish resources in WPP 714 is still dominated by small-scale fishermen using vessels <5GT (JICA 2010; Adam 2016), due to the availability of large pelagic fish resources. Therefore, monitoring the status of large pelagic fisheries in the Maluku region, especially those targeting tuna, is required.

This study aimed to examine several aspects of *T. albacares*: a) biological aspects, including length-weight relationship, b)*T. albacares* exploitation characteristics, including production trends, fishing effort, fishing grounds, fishing season, fishing gear and CPUE and c) management of tuna resources, which includes calculating the catch rate, Maximum Sustainable Yield, Maximum Economic Yield, and Total Allowable Catches of *T. albacares* in the Maluku region.

Material and Method

The research was conducted for 90 days, from March 4 to May 25, 2021, in the Banda ~~Maluku~~ Sea, by focusing on fishing ports with high tuna landing potential. Data collection was carried out at several sampling points, as shown in Figure 1.

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Figure 1. Map of research locations.

Tools and materials. The tools and materials used in this study are as follows: rulers, tape measure, digital scales, cameras, stationery, identification labels, and some samples of tuna.

Methods of data collection. In this study, the applied survey method was the field observation. Determination of the location and fishing gear was carried out by purposive sampling, namely collecting data deliberately according to the desired conditions (Tongco 2007). Meanwhile, the determination of respondents was carried out by accidental sampling, namely the accidental determination of tuna fishermen (Siburian et al 2020). Data collection for *T. albacares* sampling was carried out using the simple random sampling method, by measuring the specimens' length and weight of 10% of the total catch (Mous et al 1995). Secondary data are time series of catches and fishing effort for 5 to 10 years, from the relevant agencies.

Data collection. Primary data collection was carried out by direct observation and measurement (Hardani et al 2020) of landed *T. albacares*. The data collected included: fork length, total weight, sex, and GML. Secondary data needed is in the form of periodic data (time series) of catches and fishing effort for the last 10 years obtained from the Maritime Affairs and Fisheries Service of Maluku Province.

Data analysis

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

Length-weight relationship. The relationship between length and weight uses a linear allometric model. This model is used to calculate parameters a and b through measurements of length and weight ~~The model used to estimate the relationship between length and weight is exponential, using the following equation~~ (Brinkman, 1993; Nugraha et al 2020; Effendie 1979):

$$W = aL^b$$

Where:

~~W fish weight (g);~~
~~L standard/fork length fish (cm);~~
~~a the constant number or intercept, that is sought from the regression calculation;~~
~~b the exponent or tangential angle.~~
W: Individual weights of fish (grams)
L : Fork length fish (cm)
a : Intercept (intersection of the curve of the relationship of the length of the weight with the y-axis)
b : Slope

To determine the values of a and b, a linear regression analysis, based on the logarithm of the formula above. The linear equation becomes:

$$L_n W_{(i)} = L_n \sout{a}\ q + b L_n \sout{L}$$

Then a simple linear equation can be made (Agustian et al 2021; Muhsoni 2019):

$$Y = a + bX_{(i)}$$

Where:
~~Y =~~ Y : L_n W
X ~~-~~ : Ln ~~Lindependent~~;
a' ~~-~~ :antilog intercept;
b ~~-~~ :slope.

The coefficients of determination and correlation can also be determined through equations.

In this analysis of weight length relationships, what needs to be considered is the value of b which can be interpreted as follows:

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) (Perangin-angin et al 2015)

To determine the growth pattern, Bailey's t_{test} was needed (Thomas 2013; Nair et al 2015). The t_{test} was run to determine significant differences from the isometric value (b = 3) with significant level at 5% (P < 0.05). The formula of Bailey's t_{test} is as follows (Fauziyah et al 2021):

$$t_s = \left|\frac{3-b}{Sb}\right|$$

Information:
t_s = Bailey's t_{test}

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b = the slope of the linear regression
Sb = standard error of the b coefficients

The correlation coefficient (r) to see the closeness of the relationship between length and weight is obtained from the formula bellows (Nurhayati et al 2016).

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$$r^2 = \frac{(\sum X_i Y_i)^2}{(\sum X_i^2)(\sum Y_i^2)}$$

$$r = \sqrt{r^2}$$

Information:
r; Correlation coefficient is an abstract measure of the degree of closeness of the relationship between x and y (-1 < r < 1); 1 means that there is a close and positive relationship; -1 means that there is a close and negative relationship; and 0 means that there is no close relationship.

$$b = \frac{\Sigma Xi\ Yi}{\Sigma Xi^2}$$

Where:

$$\Sigma Xi^2 = \Sigma X^2 - \frac{(\Sigma X)^2}{N}$$

$$\Sigma Yi^2 = \Sigma Y^2 - \frac{(\Sigma Y)^2}{N}$$

$$\Sigma Xi\ Yi = \Sigma XY - \frac{(\Sigma X)(\Sigma Y)}{N}$$

Once the value of b is known, the value of a can be calculated in the following way:
a' = ȳ - bẋ
a = $e^{a'}$

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According to Effendie (1979) each value of b can be interpreted as follows:
1) If b<3, then the increase in length is faster than the increase in weight; it is called a negative allometric.
2) If b>3, then the weight gain is faster than the increase in length; it is called a positive allometric.
3) If b=3, then the increase in length and weight gain are balanced; it is called isometric allometry.

According to Effendie (1979), the T_{test} is used to determine whether the value of b obtained is significantly different from 3 or not, using the following method:

$$\Sigma d^2yx = \Sigma Yi^2 - \frac{(\Sigma XiYi)^2}{\Sigma Xi^2}$$

$$S^2yx = \frac{\Sigma d^2yx}{(N-2)}$$

$$S^2b = \Sigma Xi^2$$

$$Sb = \sqrt{S^2b}$$

$$t = \left|\frac{3-b}{Sb}\right|$$

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Where:
b = exponential value obtained in the analysis
Sb = standard deviation of Y value
t_{table} Test at 95% confidence level (n-2db)
a. If t_{count} > t_{table} then it is significantly different
b. If t_{count} < t_{table} then it is not significantly different

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The cCorrelation coefficient (r), describing the to see the close strength of the relationship between length and weight is obtained from the following formula (....et al.....):

$$r^2 = \frac{(\Sigma XiYi)^2}{(\Sigma Xi^2)(\Sigma Yi^2)}$$

$$r = \sqrt{r^2}$$

Where:
r^2 the coefficient of determination
r the correlation coefficient, is an abstract measure of the strength of the relationship between variables x and y ($-1 \leq r \leq 1$):
$r = 1$, means that there is a strong and positive relationship;
$r = -1$, means that there is a strong and negative relationship;
$r = 0$, means that there is no relationship.

Sex ratio. Comparison of the sexes of biota is done by visual observation of a number of male and female individuals obtained as samples at the study site. The sex ratio is known by using the formula:

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

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

Where: X = number of male fish
Y = number of female fish
After the sex ratio in percentage is obtained, to find out whether there is a significant difference between the ratio of male and female individuals, it is carried out through testing and the 'X^2' (chi square) test with the formula according to Effendie (1979):

$$X^2 = \frac{(fo - fh)^2}{fh}$$

Where:
X^2 = chi square
f_0 = observed biota
f_h = expected biota frequency

X^2 value obtained from this calculation, then the value is compared with the value of X^2 table with a confidence level of 95% and degrees of freedom (db) = 1 with the hypothesis:
H_0 = there is no significant difference between the number of male and female biota
H_1 = there is a significant difference between the number of male and female biota
If, $X^2_{count} < X^2_{table}$ = H_0 is accepted, H_1 is rejected
$X^2_{count} > X^2_{table}$ = H_0 is rejected, H_1 is accepted

Gonads Maturity Level (GML). The gonads maturity level of the was determined by visual observation of the morphology of the gonads. Furthermore, the observed characteristics are adjusted to the GML criteria listed in Table 1.

Table 1

Classification of Gonad Maturity Levels (GML) (Karman et al 2013)

Level	Gonadal state	Description
I	Immature	Gonads are elongated, small almost transparent
II	Maturing	Gonads are enlarged, pink-beige in color, the eggs cannot be seen with visual
III	Mature	Gonads are creamy yellow in color, eggs can be seen with visual
IV	Ripe	Eggs are enlarged and clear yellow in color, can come out

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		with a little pressure on the stomach
V	Spent	Gonads are smaller, red in color and have lots of blood vessels

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

$$m = xk + \frac{d}{2} - (X\sum Pi)$$

$$M = \text{antilog}\ (m \pm 1{,}96\sqrt{x^2\Sigma\frac{pi*qi}{n_i-1}})$$

Note:
m = logarithm of class length at first maturity
d = logarithmic difference of the mean length increase
k = number of length classes
xk = logarithm of the median length where fish are 100% gonadal mature (or p_i = 1)
p_i = proportion of gonadal mature fish in length class i with the number of fish in the i-th length interval
n_i = 1 – p_i
q_i = the number of fish in the i-th class length
M = the length of the fish when the gonads first mature is anti-log m, if ∝ = 0.05, then the confidence interval is 95% of m

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

$$SL = \frac{1}{a + \exp\ (a\text{-}b\ L)}$$

Where:
SL : Estimated Value
a : intercept
b : slope

The value of Lc was obtained by plotting the percentage of the cumulative frequency of fish caught with the standard length, where the intersection point between the 50% cumulative frequency curve is the length when 50% of the fish are caught (Diningrum et al 2019). The value of Lc can be calculated using through the formula (...)(Sparre et al 1989):

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

Catch Per Unit Effort (CPUE). Catch data and fishing effort were obtained, then tabulated to determine the value of CPUE. The fishing effort can be expressed as the number of operating days or months, the number of fishing trips or the number of fleets carrying out fishing operations. In this study the fishing effort (effort) used is expressed as the number of trips. The formula that can be used to determine the CPUE value is as follows (Imron et al 2022):

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

Where:
$CPUE_i$-catch per unit of fishing effort for the period i (tons trip^{-1});
$Catch_i$-catch for the period i (tons);
$Effort_i$-fishing effort for the period i (trip).

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Standardization of fishing gear. According to Ardelia et al (2018), standardization is done by finding the Fishing Power Index (FPI) value of each fishing gear. The fishing gear used as standard has an FPI value equal to one, while the FPI value for other fishing gear is obtained from the CPUE of the other fishing gear divided by the CPUE of the standard fishing gear. The Gulland formula for calculating FPI is as follows (Gulland 1983):

$$RFP_i = \frac{Ci/Ei}{Cs/Es}$$

Where:
RFP_i : relative fishing power factor of the i^{th} fishing unit
C_i : the number of catches of the i^{th} fishing unit
C_s : the standard number of catches of the fishing unit type
E_i : the effort of catching with the i^{th} fishing unit
E_s : the standard effort of catching with the fishing unit type

~~RFP_i~~	~~=~~	~~relative fishing power factor of the i^{th} fishing unit~~
~~C_i~~	~~=~~	~~the number of catches of the i^{th} fishing unit~~
~~C_s~~	~~=~~	~~the standard number of catches of the fishing unit type~~
~~E_i~~	~~=~~	~~the effort of catching with the i^{th} fishing unit~~
~~E_s~~	~~=~~	~~the standard effort of catching with the fishing unit type~~

After obtaining the RFP_i value, the standardized fishing effort is calculated using the formula:

$$\text{standard effort} = \sum(FPI_i \times effort_i)$$

Production surplus model. The purpose of using the Production Surplus Model is to determine the level of optimal effort, corresponding to a maximum sustainable catch without affecting long-term stock productivity which we usually call Maximum Sustainable Yield (Sari & Nurainun 2022).

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

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

Where:
Y(i) - catch for the period i, I = 1, 2, ...n;
f(i) - fishing effort for the period i.

Determining the value of a (intercept) and b (slope) requires linear regression of f(i) to Y(i)/f(i). After the a and b values are obtained, the optimum effort (f_{MSY}) and Maximum Sustainable Yield (MSY) can be calculated by the formula:

$$f_{MSY} = -\frac{a}{2b} \text{ ~~dan~~and } MSY = -\frac{a^2}{4b}$$

The level of utilization of fish resources is a fraction of the maximum Sustainable Yield (MSY):

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

Where:
Ci - number of fish caught in year I;
MSY - maximum sustainable yield.

Results and discussion

Distribution of T. albacares length frequency. Based on observations of 339 samples of *T. albacares*, the shortest length was 31 cm and the longest is 126 cm. The length frequency distribution is presented in Figure 2.

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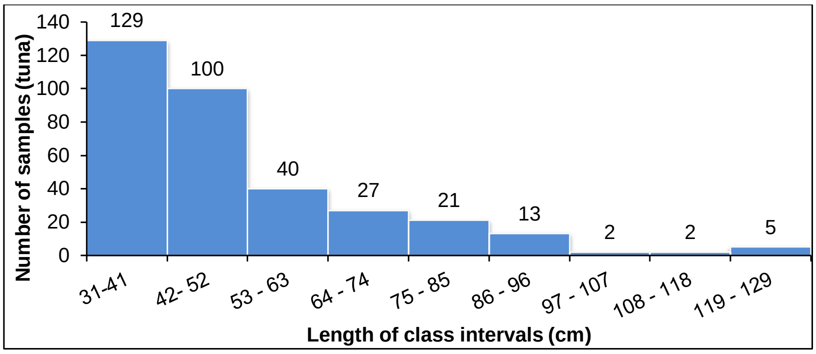

Figure 2. Length frequency distribution of *Thunnus albacares.*

The modal class interval was 31-41 cm: many small fish are caught by trolling liner and purse seiner.

The relationship between length and weight of T. albacares. The relationship between length and weight is presented on the graph, according to the characteristics of the fish growth pattern, as shown in Figure 3.

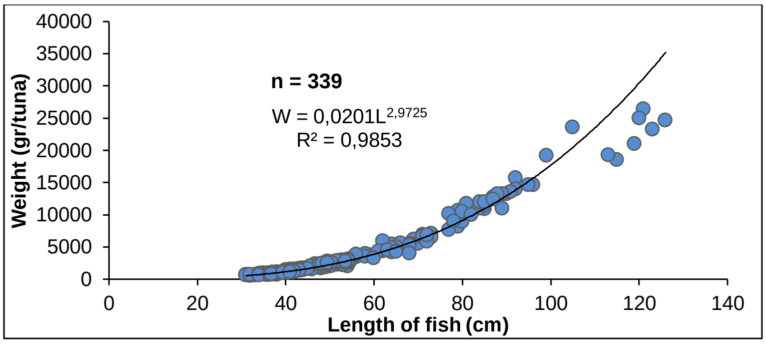

Figure 3. Length-weight relationship of *Thunnus albacares.*

From the results of the analysis of the length-weight relationship of the species *T. albacares*, the following equation was determined: W = 0.0201 $L^{2.9725}$, with a value of b = 2.9725. Then a t_{test} was carried out on the value of b at a 95% confidence interval and obtained $t_{count}<t_{table}$ ($t_{count}=1.393$; $t_{table}=1.967$), therefore H_0 was accepted, which means that the increase rates in length and weight are not significantly different, so that it can be said that the increase in length is proportional to the increase in weight (isometric).

From the results of the t_{test}, it is necessary to carry out further calculations to obtain a new *T. albacares* length-weight relationship equation, by substituting the values of $\bar{Y}$ and $\bar{X}$ using $\bar{Y}$ = a'-3$\bar{X}$, namely W=0.018055 L^3. Calculation of the growth pattern was carried out using the t_{test} (t_{count}=0.05), at a 95% confidence interval (α=0.05), producing a coefficient of determination (R^2) of 0.9928 and a correlation coefficient (r) close to 1. This shows that an increase in the length affects the weight gain, meaning that the correlation or relationship between length and fish weight is strong and positive.

Length at first capture (Lc). Calculation of the size of the first catch of *T. albacares* was carried out using data on the length and number of fish caught in purse seine catches. Based on the observation of the 70 caught specimens, the Lc was 39.55 cm as it can be seen in Figure 4.

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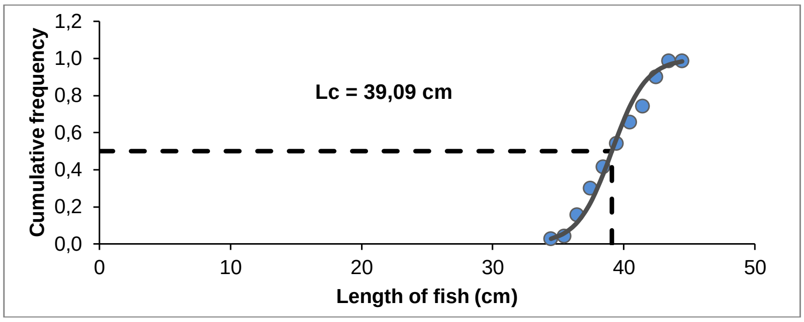

Figure 4. Length at first capture of *Thunnus albacares* on purse seine.

Fishing ground. The dominant fishing grounds for fishermen in the province of Maluku are located in the Banda Sea (FMA RI 714). These areas are usually approached by *T. albacares* due to environmental factors, food availability and they are also spawning and egg-laying areas. The highest catch occurs at the beginning of the East season, also called the harvest season, from October to December. The lean season is from May to July, the western season is from December to January and the transition season is from April to May. The catches obtained depend on the season, currents and wind, which might be obstacles for going to sea and succeeding to make catches.

Stock status in Fishery Management Area - Republic of Indonesia (FMA-RI 714) CPUE and MSY T. albacares. In table 2 below it can be seen the production data and fishing effort of *T. albacares* in FMA RI-714 by hand liner, troll liner, purse seiner, and the pole and liner.

Table 2

FMA RI-714 production and fishing effort

Year	Production (tons)					Trip			
	Purse seiner	Trolling liner	Hand liner	Pole and liner	Total	Purse seiner	Trolling liner	Hand liner	Pole and liner
2008	3,868.71	3,813.07	39.29	3,127.51	10,848.57	23,419	427,899	201	8,546
2009	3,997.51	4,961.22	1,500.39	3,754.16	14,213,28	21,373	392,497	248,406	9,457
2010	3,982.52	1,335.69	993.14	2,752.55	9,063.90	43,622	474,562	311,339	8,429
2011	4,710.08	9,739.77	2,424.13	6,639.34	23,513.32	35,888	433,171	191,396	7,641
2012	5,169.07	14,869.32	1,017.65	4,037.61	25,093.65	42,027	432,897	226,447	10,617
2013	19,288.48	10,298.59	3,125.72	3,964.70	36,677.49	32,010	484,526	186,753	10,646
2014	6,094.66	3,863.20	4,381.17	4,397.88	18,736.91	39,017	141,506	293,614	7,797
2015	4,505.92	381.21	2,587.83	5,494.17	12,969.12	34,787	247,776	85,352	8,922
2016	10,159.34	879.72	3,675.05	7,856.27	22,570.37	41,596	291,150	204,868	8,657
2017	13,102.44	1,476.79	5,140.45	8,321.75	28,041.43	38,453	226,620	191,767	8,125
2018	13,661.33	2,145.53	6,076.82	12,722.25	34,605.93	48,078	255,188	157,874	8,698

There are differences in fishing productivity between hand liner, troll liner, purse seiner, and pole and liner, it is necessary to standardize productivity, to obtain the Fishing Power Index (FPI) as can be seen in the table 3.

Table 3

Productivity and fishing power index (FPI) in *Thunnus albacares*

Year	Productivity (Tons trip^{-1})			
	Purse seine	Trolling line	Hand line	Pole and line
2008	0.1652	0.0089	0.1955	0.3660
2009	0.1870	0.0126	0.0060	0.3970
2010	0.0913	0.0028	0.0032	0.3265
2011	0.1312	0.0225	0.0127	0.8689
2012	0.1230	0.0343	0.0045	0.3803
2013	0.6026	0.0213	0.0167	0.3724
2014	0.1562	0.0273	0.0149	0.5641
2015	0.1295	0.0015	0.0303	0.6158
2016	0.2442	0.0030	0.0179	0.9075
2017	0.3407	0.0065	0.0268	1.0242
2018	0.2841	0.0084	0.0385	1.4627
Average	0.2232	0.0136	0.0334	0.6623
CPUE	0.2232	0.0136	0.0334	0.6623
FPI	0.3370	0.0204	0.0504	1

Based on Table 3, the huhate is used as standard fishing gear, because its productivity is larger than other fishing gear. Furthermore, the standardization process, resulting from the multiplication of the FPI with the number of fishing gears, produces the standard effort values presented in Table 4.

Table 4

Standardization of *Thunnus albacares* catching efforts

Year	Purse seiner	Trolling liner	Hand liner	Pole and liner	Total Effort Standard	CPUE (Ton/trip)
2008	7,892	8,765	10	8,546	25,213	0.4303
2009	7,203	8,040	12,515	9,457	37,215	0.3819
2010	14,701	9,721	15,686	8,429	48,538	0.1867
2011	12,094	8,873	9,643	7,641	38,251	0.6147
2012	14,163	8,868	11,409	10,617	45,057	0.5569
2013	10,787	9,925	9,409	10,646	40,768	0.8997
2014	13,149	2,899	14,793	7,797	38,637	0.4849
2015	11,723	5,076	4,300	8,922	30,022	0.4320
2016	14,018	5,964	10,322	8,657	38,961	0.5793
2017	12,959	4,642	9,662	8,125	35,388	0.7924
2018	16,202	5,227	7,954	8,698	38,082	0.9087

The effort and yield data shown in Table 3 will produce CPUE fluctuations every year as shown in Figure 5.

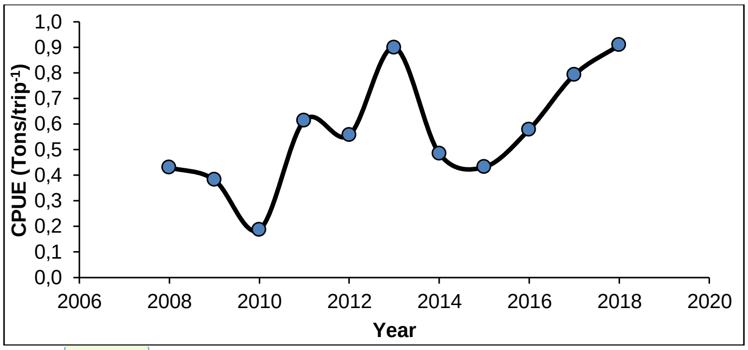

Figure 5. *Thunnus albacares* CPUE fluctuation in FMA-RI 714.

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From Figure 5 it can be concluded that 2013 was the highest CPUE point. Even though the CPUE decreased from 2014 to 2015, the conditions did not disturb the sustainability of tuna fishing activities in FMA-RI 714.

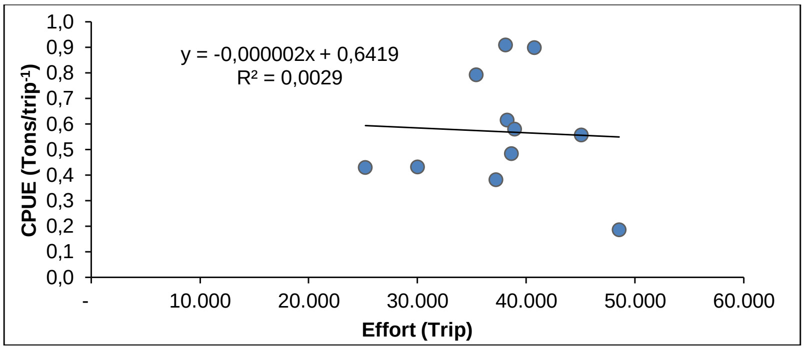

Figure 6. Linear equations of CPUE and effort *Thunnus albacares.*

The relationship between CPUE and effort in Figure 6 shows that the value of the estimation parameter for tuna fish is obtained by an intercept (a) = 0.6419 and a slope (b) = -0.000002 so as to form the Schaefer linear equation CPUE = -0.000002x + 0.6419. This relationship can be interpreted that by catching x units per year, it will reduce the CPUE value by 0.000002 tons per year. The conditions described in the linear equation produce a value of R^2 = 0.0029 which means that around 0.29% the CPUE is influenced by the effort. Thus, the R^2 value indicate that the influence of the variables used in this model is not strong.

Maximum Sustainable Yield (MSY) and Economic Maximum Sustainable Yield (EMSY) calculation data for *T. albacares* in FMA-RI 714 using the Schaefer Linear method are presented in Table 5. The results of biological analysis using the Schaefer Linear model approach can produce an MSY value of 54,027 tons with a standard effort/EMSY of 168,332 trips.

Table 5

MSY and EMSY *Thunnus albacares* Based on Schaefer linear model calculations

Year	Number of Catches (Tons)	Total Standard Effort	CPUE (Schaefer)
I	Yi	X	Y

2008	10,848.5	25,213	0.4303
2009	14,213.2	37,215	0.3819
2010	9,063.9	48,538	0.1867
2011	23,513.3	38,251	0.6147
2012	25,093.6	45,057	0.5569
2013	36,677.5	40,768	0.8997
2014	18,736.9	38,637	0.4849
2015	12,969.1	30,022	0.4320
2016	22,570.3	38,961	0.5793
2017	28,041.4	35,388	0.7924
2018	34,605.9	38,082	0.9087
Total	236,333.9	416,131	6.2676
Average	21,484.9	37,830	0.5697
Intercept a			0.6419
Slope b			-0.000002
MSY Schaefer: -a^2/4b			54,027
EMSY Schaefer: -a/2b			168,332
Total Allowable Catch (TAC) 80% MSY			43,221.80

Based on linear model calculations, biological saturation yields have not occurred in *T. albacares* from FMA RI-714, which is indicated by actual catches that are not close to their sustainable potential (MSY). This is evidenced by the actual catch in 2018 which reached 34,605.9 tonnes, not yet exceeding the potential TAC of 80% of the MSY value (43,221.80 tonnes). The sustainable potential curve (MSY) of *T. albacares* can be seen in Figure 7.

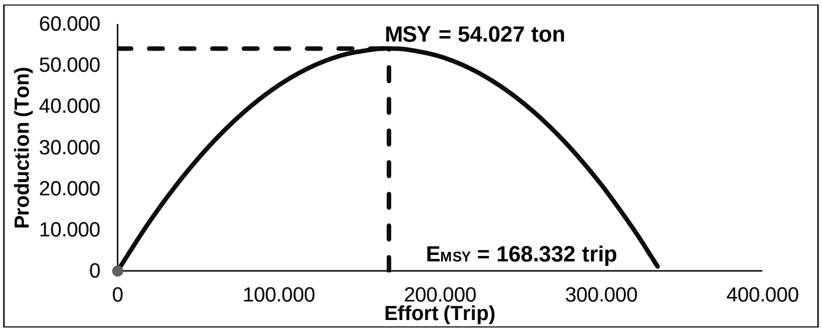

Figure 7. Stock equilibrium curve (MSY) of *Thunnus albacares* in FMA RI-714.

Conclusions. The biological aspects of *T. albacares* in Maluku waters show that the growth pattern of tuna is isometric. The exploitation of *T. albacares* is in a condition where production continues to increase with a low level of fishing gear selectivity, therefore regulating and supervising the fishing gear are required.

Conflict of interest. The author declares no conflict of interest.

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Authors:
Ratna Suharti, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: r_suharti@yahoo.com
Mira Maulita, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: maulita.stp@gmail.com
Firman Setiawan, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: firmansetiawan001@gmail.com
Dadan Zulkifli, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: belfyludaputri@gmail.com
Basuki Rachmad, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: basukibye248@gmail.com
Maman Hermawan, Faculty of Fishing Technology, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: mhermawan60@gmail.com
Mantani Sayuri, Department of Ships Navigation, Japan Agency of Maritime Education and Training for Seafarers, Marine Technical College, Ashiya City 659-0026, Hyogo, Japan, e-mail: mantani-s6ea@jmets.ac.jp
Erick Nugraha, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: nugraha_eriq1@yahoo.co.id

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Eni Kovacs <ek.bioflux@gmail.com>
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Kind regards,
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Status of the *Thunnus albacares* fishery in the Fisheries Management Area (FMA) 714, Banda Sea, Indonesia

[1]Ratna Suharti, [1]Mira Maulita, [1]Firman Setiawan, [1]Basuki Rachmad, [1]Dadan Zulkifli, [2]Mantani Sayuri, [3]Maman Hermawan, [3]Erick Nugraha

[1] Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, South Jakarta, Indonesia; [2] Department of Ships Navigation, Marine Technical College, Hyogo, Japan; [3] Faculty of Fishing Technology, Jakarta Technical University of Fisheries, South Jakarta, Indonesia. Corresponding author: E. Nugraha, nugraha_eriq1@yahoo.co.id

Abstract. The Banda Sea is a potential fishing area for large pelagic fish, especially tuna. Exploitation of this resource is carried out by various forms of fishing activities, including purse seine, pole and line, longline tuna, and handline tuna. In addition, the utilization of fish resources in FMA RI 714 is still dominated by small-scale fishermen using vessels <5 GT. Based on the large potential and condition of the available large pelagic fish resources, it is necessary to study the status of large pelagic fisheries, especially tuna in the Maluku region. This study aimed to examine the biological aspects of tuna and the fisheries management. The research was carried out from 4 March to 25 May 2021 in the Maluku Sea. This study used a survey method, namely by observing in the field the observed fish samples. Determination of the location and fishing gear was carried out by purposive sampling, while the determination of respondents was carried out by accidental sampling. The results showed that the growth pattern of *Thunnus albacares* was isometric. The size of the first caught in the purse seine for *T. albacares* was 39.09 cm Fork Length. In Fisheries Management Area of Republic Indonesia (FMA RI) 714, the actual production and tuna fishing effort shows that its utilization did not reach the maximum sustainable level and economically, tuna fishing did not yet reach the maximum profit value so that its utilization can still be increased.
Key Words: yellowfin tuna, banda sea, length of first caught, CPUE.

Introduction. The Banda Sea is located in the Eastern Indonesia Region and is included in the waters of the West Pacific Ocean, being bordered by the Indian Ocean (Firdaus 2018). The Banda Sea has also become a potential tuna fishing area in Maluku Province (Satrioajie et al 2018; Tangke et al 2011). Exploitation of tuna resources is carried out in various forms of fishing activities, including purse seiner, pole and liner, longliner and tuna handliner (Tauda et al 2021; Khan et al 2018; Widodo & Nugraha 2009). Tuna resources are spread throughout almost all Indonesian waters, from western Indonesian waters (Indian Ocean) to Eastern Indonesia (Banda Sea and North Irian Jaya) (Chodrijah & Nugraha 2013). The waters of Eastern Indonesia are known as sources for the production of tuna and skipjack, which are commonly called tuna in Indonesia (Manurung 2016). Banda Sea is a fishing ground for large pelagic fish in eastern Indonesia (Hidayat et al 2014).

Based on the results of a study of tuna stocks by the Western and Central Pacific Fisheries Commission (WCPFC) in 2012, it was reported that stocks of yellowfin tuna (*Thunnus albacares*) were not overfished, while bigeye tuna (*Thunnus obesus*) experienced overfishing (Post & Squires 2020; Hare et al 2020; Widodo et al 2015). The utilization of fish resources in WPP 714 is still dominated by small-scale fishermen using vessels <5GT (JICA 2010; Adam 2016), due to the availability of large pelagic fish resources. Therefore, monitoring the status of large pelagic fisheries in the Maluku region, especially those targeting tuna, is required.

This study aimed to examine several aspects of *T. albacares*: a) biological aspects, including length-weight relationship, b) *T. albacares* exploitation characteristics, including production trends, fishing effort, fishing grounds, fishing season, fishing gear and CPUE and c) management of tuna resources, which includes calculating the catch rate, Maximum Sustainable Yield, Maximum Economic Yield, and Total Allowable Catches of *T. albacares* in the Maluku region.

Material and Method

The research was conducted for 90 days, from March 4 to May 25, 2021, in the Banda Sea, by focusing on fishing ports with high tuna landing potential. Data collection was carried out at several sampling points, as shown in Figure 1.

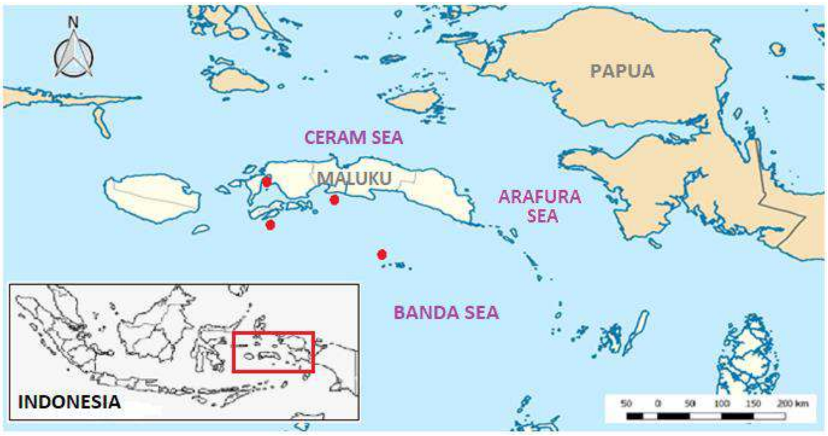

Figure 1. Map of research locations.

Tools and materials. The tools and materials used in this study are as follows: rulers, tape measure, digital scales, cameras, stationery, identification labels, and some samples of tuna.

Methods of data collection. In this study, the applied survey method was the field observation. Determination of the location and fishing gear was carried out by purposive sampling, namely collecting data deliberately according to the desired conditions (Tongco 2007). Meanwhile, the determination of respondents was carried out by accidental sampling, namely the accidental determination of tuna fishermen (Siburian et al 2020). Data collection for *T. albacares* sampling was carried out using the simple random sampling method, by measuring the specimens' length and weight of 10% of the total catch (Mous et al 1995). Secondary data are time series of catches and fishing effort for 5 to 10 years, from the relevant agencies.

Data collection. Primary data collection was carried out by direct observation and measurement (Hardani et al 2020) of landed *T. albacares*. The data collected included: fork length, total weight, sex, and GML. Secondary data needed is in the form of periodic data (time series) of catches and fishing effort for the last 10 years obtained from the Maritime Affairs and Fisheries Service of Maluku Province.

Data analysis

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

Length-weight relationship. The relationship between length and weight uses a linear allometric model. This model is used to calculate parameters a and b through measurements of length and weight (Brinkman 1993; Nugraha et al 2020; Effendie 1979):

$$W = aL^b$$

Where:
W - individual weights of fish (grams);
L - fork length fish (cm);
a - Intercept (intersection of the curve of the relationship of the length of the weight with the y-axis);
b - slope.

To determine the values of a and b, a linear regression analysis, based on the logarithm of the formula above. The linear equation becomes:

$$L_n W_{(i)} = L_n q + bL_n$$

Then a simple linear equation can be made (Agustian et al 2021; Muhsoni 2019):

$$Y = a + bX_{(i)}$$

Where:
Y - L_n W;
X - Ln;
a' - antilog intercept;
b - slope.

The coefficients of determination and correlation can also be determined through equations.

In this analysis of weight length relationships, what needs to be considered is the value of b which can be interpreted as follows:

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) (Perangin-angin et al 2015).

To determine the growth pattern, Bailey's t_{test} was needed (Thomas 2013; Nair et al 2015). The t_{test} was run to determine significant differences from the isometric value (b = 3) with significant level at 5% ($P < 0.05$). The formula of Bailey's t_{test} is as follows (Fauziyah et al 2021):

$$t_s = \left|\frac{3-b}{Sb}\right|$$

Where:
t_s - Bailey's t_{test};
b - the slope of the linear regression;
Sb - standard error of the b coefficients.

The correlation coefficient (r) to see the closeness of the relationship between length and weight is obtained from the formula bellows (Nurhayati et al 2016).

$$r^2 = \frac{(\sum X_i Y_i)^2}{(\sum X_i^2)(\sum Y_i^2)}$$

$$r = \sqrt{r^2}$$

Where:
r; Correlation coefficient is an abstract measure of the degree of closeness of the relationship between x and y ($-1 < r < 1$);
1 means that there is a close and positive relationship;
-1 means that there is a close and negative relationship;
0 means that there is no close relationship.

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

$$SL = \frac{1}{a + \exp\,(a - b\,L)}$$

Where:
SL - estimated value;
a – intercept;
b – slope.

The value of Lc was obtained by plotting the percentage of the cumulative frequency of fish caught with the standard length, where the intersection point between the 50% cumulative frequency curve is the length when 50% of the fish are caught (Diningrum et al 2019). The value of Lc can be calculated through the formula (Sparre et al 1989):

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

Catch Per Unit Effort (CPUE). Catch data and fishing effort were obtained, then tabulated to determine the value of CPUE. The fishing effort can be expressed as the number of operating days or months, the number of fishing trips or the number of fleets carrying out fishing operations. In this study the fishing effort (effort) used is expressed as the number of trips. The formula that can be used to determine the CPUE value is as follows (Imron et al 2022):

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

Where:
$CPUE_i$ - catch per unit of fishing effort for the period i (tons trip^{-1});
$Catch_i$ - catch for the period i (tons);
$Effort_i$ - fishing effort for the period i (trip).

Standardization of fishing gear. According to Ardelia et al (2018), standardization is done by finding the Fishing Power Index (FPI) value of each fishing gear. The fishing gear used as standard has an FPI value equal to one, while the FPI value for other fishing gear is obtained from the CPUE of the other fishing gear divided by the CPUE of the standard fishing gear. The Gulland formula for calculating FPI is as follows (Gulland 1983):

$$RFP_i = \frac{Ci/Ei}{Cs/Es}$$

Where:
RFP_i - relative fishing power factor of the i^{th} fishing unit;
C_i - the number of catches of the i^{th} fishing unit;
C_s - the standard number of catches of the fishing unit type;
E_i - the effort of catching with the i^{th} fishing unit;
E_s - the standard effort of catching with the fishing unit type.

After obtaining the RFP_i value, the standardized fishing effort is calculated using the formula:

$$\text{Standard effort} = \sum(FPI_i \times effort_i)$$

Production surplus model. The purpose of using the Production Surplus Model is to determine the level of optimal effort, corresponding to a maximum sustainable catch without affecting long-term stock productivity which we usually call Maximum Sustainable Yield (Sari & Nurainun 2022).

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

$$CPUE = \frac{Y}{f} = \frac{Y(i)}{f(i)}, i = 1, 2, ... n$$

Where:
Y(i) - catch for the period i, I = 1, 2, ...n;
f(i) - fishing effort for the period i.

Determining the value of a (intercept) and b (slope) requires linear regression off(i) to Y(i)/f(i). After the a and b values are obtained, the optimum effort (f_{MSY}) and Maximum Sustainable Yield (MSY) can be calculated by the formula:

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

Commented [A1]: source?
Commented [WU2R1]: As requested before?!

The level of utilization of fish resources is a fraction of the maximum Sustainable Yield (MSY):

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

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Where:
Ci - number of fish caught in year I;
MSY - maximum sustainable yield.

Results and discussion

Distribution of T. albacares length frequency. Based on observations of 339 samples of *T. albacares*, the shortest length was 31 cm and the longest is 126 cm. The length frequency distribution is presented in Figure 2.

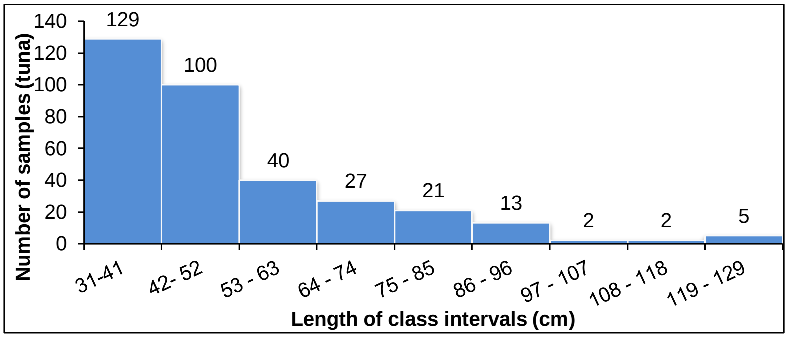

Figure 2. Length frequency distribution of *Thunnus albacares.*

The modal class interval was 31-41 cm: many small fish are caught by trolling liner and purse seiner.

The relationship between length and weight of T. albacares. The relationship between length and weight is presented on the graph, according to the characteristics of the fish growth pattern, as shown in Figure 3.

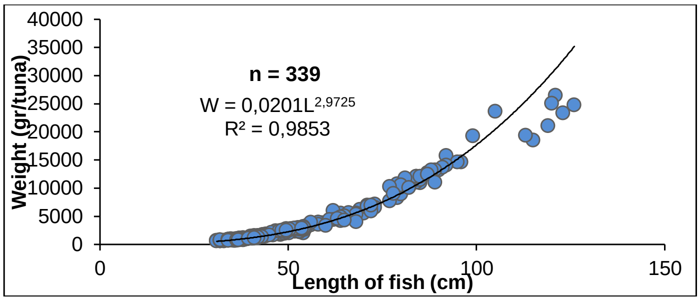

Figure 3. Length-weight relationship of *Thunnus albacares.*

From the results of the analysis of the length-weight relationship of the species *T. albacares*, the following equation was determined: $W=0.0201\ L^{2.9725}$, with a value of b=2.9725. Then a t_{-test} was carried out on the value of b at a 95% confidence interval and obtained $t_{count}<t_{table}$ ($t_{count}=1.393$; $t_{table}=1.967$), therefore H_0 was accepted, which means that the increase rates in length and weight are not significantly different, so that it can be said that the increase in length is proportional to the increase in weight (isometric).

From the results of the t_{test}, it is necessary to carry out further calculations to obtain a new *T. albacares* length-weight relationship equation, by substituting the values of $\bar{Y}$ and $\bar{X}$ using $\bar{Y} = a'-3\bar{X}$, namely $W=0.018055\ L^3$. Calculation of the growth pattern was carried out using the $t_{\ test}$ ($t_{count}=0.05$), at a 95% confidence interval ($\alpha=0.05$), producing a coefficient of determination (R^2) of 0.9928 and a correlation coefficient (r) close to 1. This shows that an increase in the length affects the weight gain, meaning that the correlation or relationship between length and fish weight is strong and positive.

Length at first capture (Lc). Calculation of the size of the first catch of *T. albacares* was carried out using data on the length and number of fish caught in purse seine catches. Based on the observation of the 70 caught specimens, the Lc was 39.55 cm as it can be seen in Figure 4.

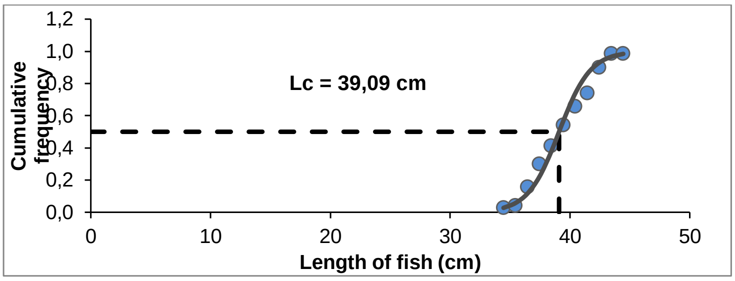

Figure 4. Length at first capture of *Thunnus albacares* on purse seine.

Fishing ground. The dominant fishing grounds for fishermen in the province of Maluku are located in the Banda Sea (FMA RI 714). These areas are usually approached by *T. albacares* due to environmental factors, food availability and they are also spawning and egg-laying areas. The highest catch occurs at the beginning of the East season, also called the harvest season, from October to December. The lean season is from May to July, the western season is from December to January and the transition season is from April to May. The catches obtained depend on the season, currents and wind, which might be obstacles for going to sea and succeeding to make catches.

Stock status in Fishery Management Area - Republic of Indonesia (FMA-RI 714)

CPUE and MSY T. albacares. In Table 2 it can be seen the production data and fishing effort of *T. albacares* in FMA RI-714 by hand liner, troll liner, purse seiner, and the pole and liner.

Table 2

FMA RI-714 production and fishing effort

Year	*Production (tons)*					*Trip*			
	Purse seiner	*Trolling liner*	*Hand liner*	*Pole and liner*	*Total*	*Purse seiner*	*Trolling liner*	*Hand liner*	*Pole and liner*
2008	3,868.71	3,813.07	39.29	3,127.51	10,848.57	23,419	427,899	201	8,546
2009	3,997.51	4,961.22	1,500.39	3,754.16	14,213,28	21,373	392,497	248,406	9,457
2010	3,982.52	1,335.69	993.14	2,752.55	9,063.90	43,622	474,562	311,339	8,429
2011	4,710.08	9,739.77	2,424.13	6,639.34	23,513.32	35,888	433,171	191,396	7,641
2012	5,169.07	14,869.32	1,017.65	4,037.61	25,093.65	42,027	432,897	226,447	10,617
2013	19,288.48	10,298.59	3,125.72	3,964.70	36,677.49	32,010	484,526	186,753	10,646
2014	6,094.66	3,863.20	4,381.17	4,397.88	18,736.91	39,017	141,506	293,614	7,797
2015	4,505.92	381.21	2,587.83	5,494.17	12,969.12	34,787	247,776	85,352	8,922
2016	10,159.34	879.72	3,675.05	7,856.27	22,570.37	41,596	291,150	204,868	8,657
2017	13,102.44	1,476.79	5,140.45	8,321.75	28,041.43	38,453	226,620	191,767	8,125
2018	13,661.33	2,145.53	6,076.82	12,722.25	34,605.93	48,078	255,188	157,874	8,698

There are differences in fishing productivity between hand liner, troll liner, purse seiner, and pole and liner, it is necessary to standardize productivity, to obtain the Fishing Power Index (FPI) as can be seen in the Table 3.

Table 3

Productivity and fishing power index (FPI) in *Thunnus albacares*

Year	*Productivity (tons trip^{-1})*			
	Purse seine	*Trolling line*	*Hand line*	*Pole and line*
2008	0.1652	0.0089	0.1955	0.3660
2009	0.1870	0.0126	0.0060	0.3970
2010	0.0913	0.0028	0.0032	0.3265
2011	0.1312	0.0225	0.0127	0.8689
2012	0.1230	0.0343	0.0045	0.3803
2013	0.6026	0.0213	0.0167	0.3724
2014	0.1562	0.0273	0.0149	0.5641
2015	0.1295	0.0015	0.0303	0.6158
2016	0.2442	0.0030	0.0179	0.9075
2017	0.3407	0.0065	0.0268	1.0242
2018	0.2841	0.0084	0.0385	1.4627
Average	0.2232	0.0136	0.0334	0.6623
CPUE	0.2232	0.0136	0.0334	0.6623
FPI	0.3370	0.0204	0.0504	1

Based on Table 3, the huhate is used as standard fishing gear, because its productivity is larger than other fishing gear. Furthermore, the standardization process, resulting from the multiplication of the FPI with the number of fishing gears, produces the standard effort values presented in Table 4.

Table 4

Standardization of *Thunnus albacares* catching efforts

Year	*Purse seiner*	*Trolling liner*	*Hand liner*	*Pole and liner*	*Total effort standard*	*CPUE (ton trip^{-1})*
2008	7,892	8,765	10	8,546	25,213	0.4303
2009	7,203	8,040	12,515	9,457	37,215	0.3819
2010	14,701	9,721	15,686	8,429	48,538	0.1867

Year	Purse seiner	Trolling liner	Hand liner	Pole and liner	Total effort standard	CPUE (ton trip^{-1})
2011	12,094	8,873	9,643	7,641	38,251	0.6147
2012	14,163	8,868	11,409	10,617	45,057	0.5569
2013	10,787	9,925	9,409	10,646	40,768	0.8997
2014	13,149	2,899	14,793	7,797	38,637	0.4849
2015	11,723	5,076	4,300	8,922	30,022	0.4320
2016	14,018	5,964	10,322	8,657	38,961	0.5793
2017	12,959	4,642	9,662	8,125	35,388	0.7924
2018	16,202	5,227	7,954	8,698	38,082	0.9087

The effort and yield data shown in Table 3 will produce CPUE fluctuations every year as shown in Figure 5.

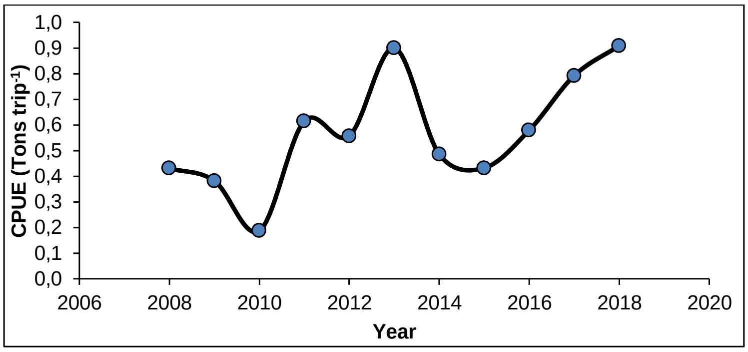

Figure 5. *Thunnus albacares* CPUE fluctuation in FMA-RI 714.

From Figure 5 it can be concluded that 2013 was the highest CPUE point. Even though the CPUE decreased from 2014 to 2015, the conditions did not disturb the sustainability of tuna fishing activities in FMA-RI 714.

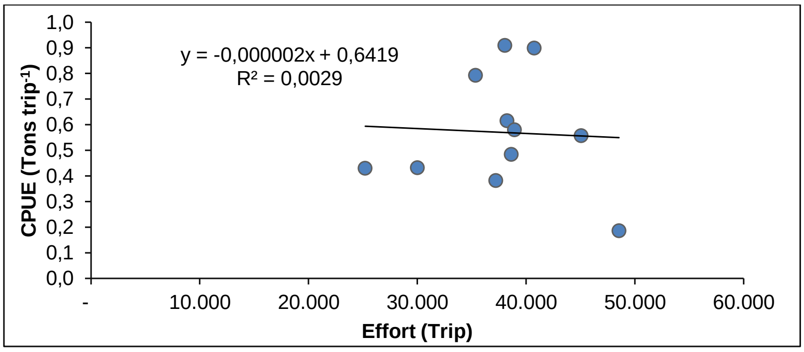

Figure 6. Linear equations of CPUE and effort *Thunnus albacares.*

The relationship between CPUE and effort in Figure 6 shows that the value of the estimation parameter for tuna fish is obtained by an intercept (a) = 0.6419 and a slope (b) = -0.000002 so as to form the Schaefer linear equation CPUE = -0.000002x + 0.6419. This relationship can be interpreted that by catching x units per year, it will reduce the CPUE value by 0.000002 tons per year. The conditions described in the linear equation produce a value of R^2 = 0.0029 which means that around 0.29% the CPUE is influenced

by the effort. Thus, the R^2 value indicate that the influence of the variables used in this model is not strong.

Maximum Sustainable Yield (MSY) and Economic Maximum Sustainable Yield (EMSY) calculation data for *T. albacares* in FMA-RI 714 using the Schaefer Linear method are presented in Table 5. The results of biological analysis using the Schaefer Linear model approach can produce an MSY value of 54,027 tons with a standard effort/EMSY of 168,332 trips.

Table 5

MSY and EMSY *Thunnus albacares* Based on Schaefer linear model calculations

Year	*Number of catches (Tons)*	*Total standard effort*	*CPUE (Schaefer)*
I	*Yi*	*X*	*Y*
2008	10,848.5	25,213	0.4303
2009	14,213.2	37,215	0.3819
2010	9,063.9	48,538	0.1867
2011	23,513.3	38,251	0.6147
2012	25,093.6	45,057	0.5569
2013	36,677.5	40,768	0.8997
2014	18,736.9	38,637	0.4849
2015	12,969.1	30,022	0.4320
2016	22,570.3	38,961	0.5793
2017	28,041.4	35,388	0.7924
2018	34,605.9	38,082	0.9087
Total	236,333.9	416,131	6.2676
Average	21,484.9	37,830	0.5697
	Intercept a		0.6419
	Slope b		-0.000002
	MSY Schaefer: -a^2/4b		54,027
	EMSY Schaefer: -a/2b		168,332
	Total Allowable Catch (TAC) 80% MSY		43,221.80

Based on linear model calculations, biological saturation yields have not occurred in *T. albacares* from FMA RI-714, which is indicated by actual catches that are not close to their sustainable potential (MSY). This is evidenced by the actual catch in 2018 which reached 34,605.9 tonnes, not yet exceeding the potential TAC of 80% of the MSY value (43,221.80 tonnes). The sustainable potential curve (MSY) of *T. albacares* can be seen in Figure 7.

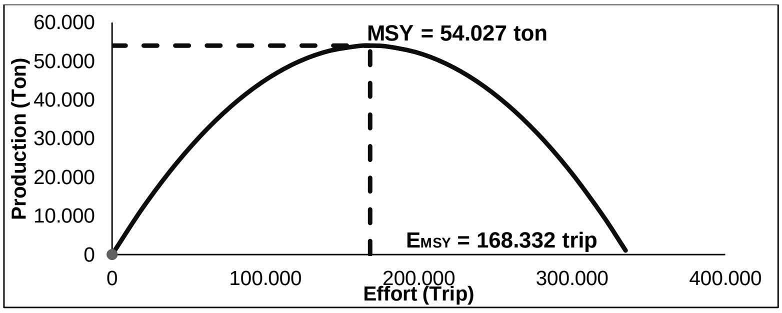

Figure 7. Stock equilibrium curve (MSY) of *Thunnus albacares* in FMA RI-714.

Conclusions. The biological aspects of *T. albacares* in Maluku waters show that the growth pattern of tuna is isometric. The exploitation of *T. albacares* is in a condition where

production continues to increase with a low level of fishing gear selectivity, therefore regulating and supervising the fishing gear are required.

Conflict of interest. The author declares no conflict of interest.

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Authors:
Ratna Suharti, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: r_suharti@yahoo.com
Mira Maulita, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: maulita.stp@gmail.com
Firman Setiawan, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: firmansetiawan001@gmail.com
Dadan Zulkifli, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: belfyludaputri@gmail.com
Basuki Rachmad, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: basukibye248@gmail.com
Maman Hermawan, Faculty of Fishing Technology, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: mhermawan60@gmail.com
Mantani Sayuri, Department of Ships Navigation, Japan Agency of Maritime Education and Training for Seafarers, Marine Technical College, Ashiya City 659-0026, Hyogo, Japan, e-mail: mantani-s6ea@jmets.ac.jp
Erick Nugraha, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: nugraha_eriq1@yahoo.co.id

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Status of the *Thunnus albacares* fishery in the Fisheries Management Area (FMA) 714, Banda Sea, Indonesia

[1]Ratna Suharti, [1]Mira Maulita, [1]Firman Setiawan, [1]Basuki Rachmad, [1]Dadan Zulkifli, [2]Mantani Sayuri, [3]Maman Hermawan, [3]Erick Nugraha

[1] Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, South Jakarta, Indonesia; [2] Department of Ships Navigation, Marine Technical College, Hyogo, Japan; [3] Faculty of Fishing Technology, Jakarta Technical University of Fisheries, South Jakarta, Indonesia. Corresponding author: E. Nugraha, nugraha_eriq1@yahoo.co.id

Abstract. The Banda Sea is a potential fishing area for large pelagic fish, especially tuna. Exploitation of this resource is carried out by various forms of fishing activities, including purse seine, pole and line, longline tuna, and handline tuna. In addition, the utilization of fish resources in FMA RI 714 is still dominated by small-scale fishermen using vessels <5 GT. Based on the large potential and condition of the available large pelagic fish resources, it is necessary to study the status of large pelagic fisheries, especially tuna in the Maluku region. This study aimed to examine the biological aspects of tuna and the fisheries management. The research was carried out from 4 March to 25 May 2021 in the Maluku Sea. This study used a survey method, namely by observing in the field the observed fish samples. Determination of the location and fishing gear was carried out by purposive sampling, while the determination of respondents was carried out by accidental sampling. The results showed that the growth pattern of *Thunnus albacares* was isometric. The size of the first caught in the purse seine for *T. albacares* was 39.09 cm Fork Length. In Fisheries Management Area of Republic Indonesia (FMA RI) 714, the actual production and tuna fishing effort shows that its utilization did not reach the maximum sustainable level and economically, tuna fishing did not yet reach the maximum profit value so that its utilization can still be increased.
Key Words: yellowfin tuna, banda sea, length of first caught, CPUE.

Introduction. The Banda Sea is located in the Eastern Indonesia Region and is included in the waters of the West Pacific Ocean, being bordered by the Indian Ocean (Firdaus 2018). The Banda Sea has also become a potential tuna fishing area in Maluku Province (Satrioajie et al 2018; Tangke et al 2011). Exploitation of tuna resources is carried out in various forms of fishing activities, including purse seiner, pole and liner, longliner and tuna handliner (Tauda et al 2021; Khan et al 2018; Widodo & Nugraha 2009). Tuna resources are spread throughout almost all Indonesian waters, from western Indonesian waters (Indian Ocean) to Eastern Indonesia (Banda Sea and North Irian Jaya) (Chodrijah & Nugraha 2013). The waters of Eastern Indonesia are known as sources for the production of tuna and skipjack, which are commonly called tuna in Indonesia (Manurung 2016). Banda Sea is a fishing ground for large pelagic fish in eastern Indonesia (Hidayat et al 2014).

Based on the results of a study of tuna stocks by the Western and Central Pacific Fisheries Commission (WCPFC) in 2012, it was reported that stocks of yellowfin tuna (*Thunnus albacares*) were not overfished, while bigeye tuna (*Thunnus obesus*) experienced overfishing (Post & Squires 2020; Hare et al 2020; Widodo et al 2015). The utilization of fish resources in WPP 714 is still dominated by small-scale fishermen using vessels <5GT (JICA 2010; Adam 2016), due to the availability of large pelagic fish resources. Therefore, monitoring the status of large pelagic fisheries in the Maluku region, especially those targeting tuna, is required.

This study aimed to examine several aspects of *T. albacares*: a) biological aspects, including length-weight relationship, b) *T. albacares* exploitation characteristics, including production trends, fishing effort, fishing grounds, fishing season, fishing gear and CPUE and c) management of tuna resources, which includes calculating the catch rate, Maximum Sustainable Yield, Maximum Economic Yield, and Total Allowable Catches of *T. albacares* in the Maluku region.

Material and Method

The research was conducted for 90 days, from March 4 to May 25, 2021, in the Banda Sea, by focusing on fishing ports with high tuna landing potential. Data collection was carried out at several sampling points, as shown in Figure 1.

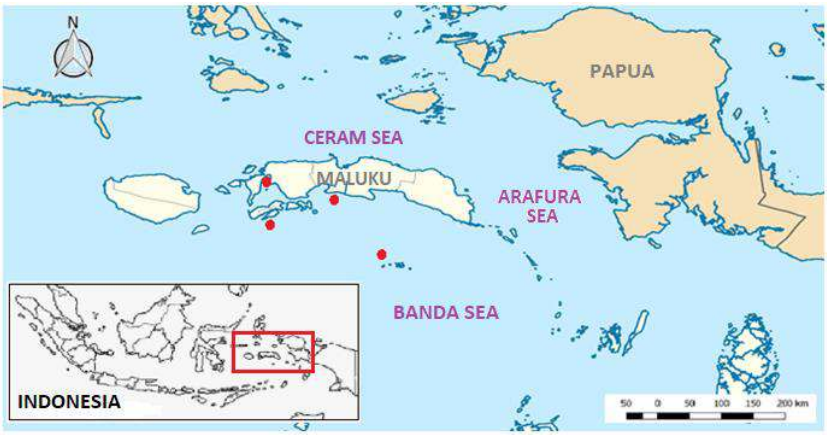

Figure 1. Map of research locations.

Tools and materials. The tools and materials used in this study are as follows: rulers, tape measure, digital scales, cameras, stationery, identification labels, and some samples of tuna.

Methods of data collection. In this study, the applied survey method was the field observation. Determination of the location and fishing gear was carried out by purposive sampling, namely collecting data deliberately according to the desired conditions (Tongco 2007). Meanwhile, the determination of respondents was carried out by accidental sampling, namely the accidental determination of tuna fishermen (Siburian et al 2020). Data collection for *T. albacares* sampling was carried out using the simple random sampling method, by measuring the specimens' length and weight of 10% of the total catch (Mous et al 1995). Secondary data are time series of catches and fishing effort for 5 to 10 years, from the relevant agencies.

Data collection. Primary data collection was carried out by direct observation and measurement (Hardani et al 2020) of landed *T. albacares*. The data collected included: fork length, total weight, sex, and GML. Secondary data needed is in the form of periodic data (time series) of catches and fishing effort for the last 10 years obtained from the Maritime Affairs and Fisheries Service of Maluku Province.

Data analysis

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

Length-weight relationship. The relationship between length and weight uses a linear allometric model. This model is used to calculate parameters a and b through measurements of length and weight (Brinkman 1993; Nugraha et al 2020; Effendie 1979):

$$W = aL^b$$

Where:
W - individual weights of fish (grams);
L - fork length fish (cm);
a - Intercept (intersection of the curve of the relationship of the length of the weight with the y-axis);
b - slope.

To determine the values of a and b, a linear regression analysis, based on the logarithm of the formula above. The linear equation becomes:

$$L_n W_{(i)} = L_n q + bL_n$$

Then a simple linear equation can be made (Agustian et al 2021; Muhsoni 2019):

$$Y = a + bX_{(i)}$$

Where:
Y - L_n W;
X - Ln;
a' - antilog intercept;
b - slope.

The coefficients of determination and correlation can also be determined through equations.

In this analysis of weight length relationships, what needs to be considered is the value of b which can be interpreted as follows:

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) (Perangin-angin et al 2015).

To determine the growth pattern, Bailey's t_{test} was needed (Thomas 2013; Nair et al 2015). The t_{test} was run to determine significant differences from the isometric value (b = 3) with significant level at 5% ($P < 0.05$). The formula of Bailey's t_{test} is as follows (Fauziyah et al 2021):

$$t_s = \left|\frac{3-b}{Sb}\right|$$

Where:
t_s - Bailey's t_{test};
b - the slope of the linear regression;
Sb - standard error of the b coefficients.

The correlation coefficient (r) to see the closeness of the relationship between length and weight is obtained from the formula bellows (Nurhayati et al 2016).

$$r^2 = \frac{(\sum X_i Y_i)^2}{(\sum X_i^2)(\sum Y_i^2)}$$

$$r = \sqrt{r^2}$$

Where:
r; Correlation coefficient is an abstract measure of the degree of closeness of the relationship between x and y ($-1 < r < 1$);
1 means that there is a close and positive relationship;
-1 means that there is a close and negative relationship;
0 means that there is no close relationship.

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

$$SL = \frac{1}{a + \exp(a - b\,L)}$$

Where:
SL - estimated value;
a – intercept;
b – slope.

The value of Lc was obtained by plotting the percentage of the cumulative frequency of fish caught with the standard length, where the intersection point between the 50% cumulative frequency curve is the length when 50% of the fish are caught (Diningrum et al 2019). The value of Lc can be calculated through the formula (Sparre et al 1989):

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

Catch Per Unit Effort (CPUE). Catch data and fishing effort were obtained, then tabulated to determine the value of CPUE. The fishing effort can be expressed as the number of operating days or months, the number of fishing trips or the number of fleets carrying out fishing operations. In this study the fishing effort (effort) used is expressed as the number of trips. The formula that can be used to determine the CPUE value is as follows (Imron et al 2022):

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

Where:
$CPUE_i$ - catch per unit of fishing effort for the period i (tons trip^{-1});
$Catch_i$ - catch for the period i (tons);
$Effort_i$ - fishing effort for the period i (trip).

Standardization of fishing gear. According to Ardelia et al (2018), standardization is done by finding the Fishing Power Index (FPI) value of each fishing gear. The fishing gear used as standard has an FPI value equal to one, while the FPI value for other fishing gear is obtained from the CPUE of the other fishing gear divided by the CPUE of the standard fishing gear. The Gulland formula for calculating FPI is as follows (Gulland 1983):

$$RFP_i = \frac{Ci/Ei}{Cs/Es}$$

Where:
RFP_i - relative fishing power factor of the i^{th} fishing unit;
C_i - the number of catches of the i^{th} fishing unit;
C_s - the standard number of catches of the fishing unit type;
E_i - the effort of catching with the i^{th} fishing unit;
E_s - the standard effort of catching with the fishing unit type.

After obtaining the RFP_i value, the standardized fishing effort is calculated using the formula:

$$\text{Standard effort} = \sum(FPI_i \times effort_i)$$

Production surplus model. The purpose of using the Production Surplus Model is to determine the level of optimal effort, corresponding to a maximum sustainable catch without affecting long-term stock productivity which we usually call Maximum Sustainable Yield (Sari & Nurainun 2022).

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

$$CPUE = \frac{Y}{f} = \frac{Y(i)}{f(i)}, i = 1, 2, ... n$$

Where:
Y(i) - catch for the period i, I = 1, 2, ...n;
f(i) - fishing effort for the period i.

Determining the value of a (intercept) and b (slope) requires linear regression off(i) to Y(i)/f(i). After the a and b values are obtained, the optimum effort (f_{MSY}) and Maximum Sustainable Yield (MSY) can be calculated by the formula (Kartini et al 2021):

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

The level of utilization of fish resources is a fraction of the maximum Sustainable Yield (MSY) (Zahra et al 2019):

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

Where:
Ci - number of fish caught in year I;
MSY - maximum sustainable yield.

Results and discussion

Distribution of T. albacares length frequency. Based on observations of 339 samples of *T. albacares*, the shortest length was 31 cm and the longest is 126 cm. The length frequency distribution is presented in Figure 2.

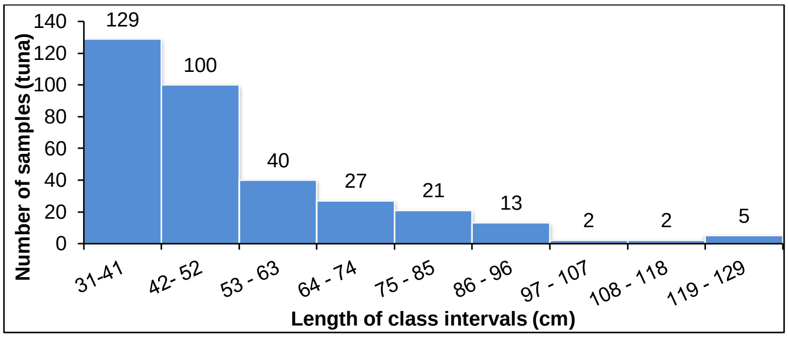

Figure 2. Length frequency distribution of *Thunnus albacares.*

The modal class interval was 31-41 cm: many small fish are caught by trolling liner and purse seiner.

The relationship between length and weight of T. albacares. The relationship between length and weight is presented on the graph, according to the characteristics of the fish growth pattern, as shown in Figure 3.

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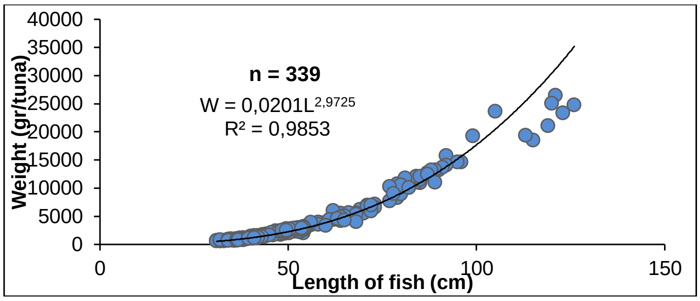

Figure 3. Length-weight relationship of *Thunnus albacares.*

From the results of the analysis of the length-weight relationship of the species *T. albacares*, the following equation was determined: $W=0.0201\ L^{2.9725}$, with a value of b=2.9725. Then a t_{-test} was carried out on the value of b at a 95% confidence interval and obtained $t_{count}<t_{table}$ ($t_{count}=1.393$; $t_{table}=1.967$), therefore H_0 was accepted, which means that the increase rates in length and weight are not significantly different, so that it can be said that the increase in length is proportional to the increase in weight (isometric).

From the results of the t_{test}, it is necessary to carry out further calculations to obtain a new *T. albacares* length-weight relationship equation, by substituting the values of $\bar{Y}$ and $\bar{X}$ using $\bar{Y} = a'-3\bar{X}$, namely $W=0.018055\ L^3$. Calculation of the growth pattern was carried out using the t_{test} ($t_{count}=0.05$), at a 95% confidence interval ($\alpha=0.05$), producing a coefficient of determination (R^2) of 0.9928 and a correlation coefficient (r) close to 1. This shows that an increase in the length affects the weight gain, meaning that the correlation or relationship between length and fish weight is strong and positive.

Length at first capture (Lc). Calculation of the size of the first catch of *T. albacares* was carried out using data on the length and number of fish caught in purse seine catches. Based on the observation of the 70 caught specimens, the Lc was 39.55 cm as it can be seen in Figure 4.

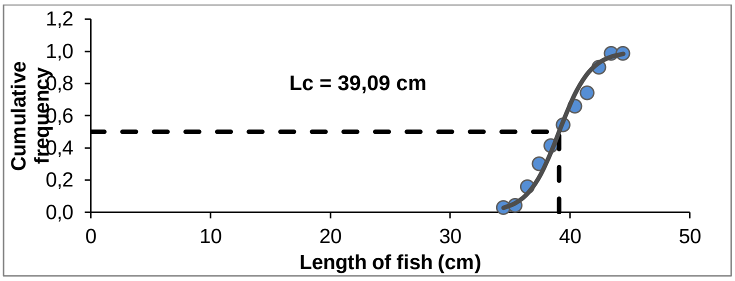

Figure 4. Length at first capture of *Thunnus albacares* on purse seine.

Fishing ground. The dominant fishing grounds for fishermen in the province of Maluku are located in the Banda Sea (FMA RI 714). These areas are usually approached by *T. albacares* due to environmental factors, food availability and they are also spawning and egg-laying areas. The highest catch occurs at the beginning of the East season, also called the harvest season, from October to December. The lean season is from May to July, the western season is from December to January and the transition season is from April to May. The catches obtained depend on the season, currents and wind, which might be obstacles for going to sea and succeeding to make catches.

Stock status in Fishery Management Area - Republic of Indonesia (FMA-RI 714)

CPUE and MSY T. albacares. In Table 2 it can be seen the production data and fishing effort of *T. albacares* in FMA RI-714 by hand liner, troll liner, purse seiner, and the pole and liner.

Table 2

FMA RI-714 production and fishing effort

Year	*Production (tons)*					*Trip*			
	Purse seiner	*Trolling liner*	*Hand liner*	*Pole and liner*	*Total*	*Purse seiner*	*Trolling liner*	*Hand liner*	*Pole and liner*
2008	3,868.71	3,813.07	39.29	3,127.51	10,848.57	23,419	427,899	201	8,546
2009	3,997.51	4,961.22	1,500.39	3,754.16	14,213,28	21,373	392,497	248,406	9,457
2010	3,982.52	1,335.69	993.14	2,752.55	9,063.90	43,622	474,562	311,339	8,429
2011	4,710.08	9,739.77	2,424.13	6,639.34	23,513.32	35,888	433,171	191,396	7,641
2012	5,169.07	14,869.32	1,017.65	4,037.61	25,093.65	42,027	432,897	226,447	10,617
2013	19,288.48	10,298.59	3,125.72	3,964.70	36,677.49	32,010	484,526	186,753	10,646
2014	6,094.66	3,863.20	4,381.17	4,397.88	18,736.91	39,017	141,506	293,614	7,797
2015	4,505.92	381.21	2,587.83	5,494.17	12,969.12	34,787	247,776	85,352	8,922
2016	10,159.34	879.72	3,675.05	7,856.27	22,570.37	41,596	291,150	204,868	8,657
2017	13,102.44	1,476.79	5,140.45	8,321.75	28,041.43	38,453	226,620	191,767	8,125
2018	13,661.33	2,145.53	6,076.82	12,722.25	34,605.93	48,078	255,188	157,874	8,698

There are differences in fishing productivity between hand liner, troll liner, purse seiner, and pole and liner, it is necessary to standardize productivity, to obtain the Fishing Power Index (FPI) as can be seen in the Table 3.

Table 3

Productivity and fishing power index (FPI) in *Thunnus albacares*

Year	*Productivity (tons trip^{-1})*			
	Purse seine	*Trolling line*	*Hand line*	*Pole and line*
2008	0.1652	0.0089	0.1955	0.3660
2009	0.1870	0.0126	0.0060	0.3970
2010	0.0913	0.0028	0.0032	0.3265
2011	0.1312	0.0225	0.0127	0.8689
2012	0.1230	0.0343	0.0045	0.3803
2013	0.6026	0.0213	0.0167	0.3724
2014	0.1562	0.0273	0.0149	0.5641
2015	0.1295	0.0015	0.0303	0.6158
2016	0.2442	0.0030	0.0179	0.9075
2017	0.3407	0.0065	0.0268	1.0242
2018	0.2841	0.0084	0.0385	1.4627
Average	0.2232	0.0136	0.0334	0.6623
CPUE	0.2232	0.0136	0.0334	0.6623
FPI	0.3370	0.0204	0.0504	1

Based on Table 3, the huhate is used as standard fishing gear, because its productivity is larger than other fishing gear. Furthermore, the standardization process, resulting from the multiplication of the FPI with the number of fishing gears, produces the standard effort values presented in Table 4.

Table 4

Standardization of *Thunnus albacares* catching efforts

Year	*Purse seiner*	*Trolling liner*	*Hand liner*	*Pole and liner*	*Total effort standard*	*CPUE (ton trip^{-1})*
2008	7,892	8,765	10	8,546	25,213	0.4303
2009	7,203	8,040	12,515	9,457	37,215	0.3819
2010	14,701	9,721	15,686	8,429	48,538	0.1867

Year	Purse seiner	Trolling liner	Hand liner	Pole and liner	Total effort standard	CPUE (ton trip^{-1})
2011	12,094	8,873	9,643	7,641	38,251	0.6147
2012	14,163	8,868	11,409	10,617	45,057	0.5569
2013	10,787	9,925	9,409	10,646	40,768	0.8997
2014	13,149	2,899	14,793	7,797	38,637	0.4849
2015	11,723	5,076	4,300	8,922	30,022	0.4320
2016	14,018	5,964	10,322	8,657	38,961	0.5793
2017	12,959	4,642	9,662	8,125	35,388	0.7924
2018	16,202	5,227	7,954	8,698	38,082	0.9087

The effort and yield data shown in Table 3 will produce CPUE fluctuations every year as shown in Figure 5.

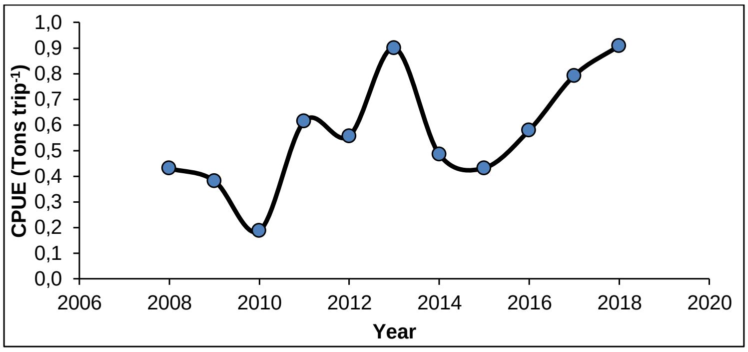

Figure 5. *Thunnus albacares* CPUE fluctuation in FMA-RI 714.

From Figure 5 it can be concluded that 2013 was the highest CPUE point. Even though the CPUE decreased from 2014 to 2015, the conditions did not disturb the sustainability of tuna fishing activities in FMA-RI 714.

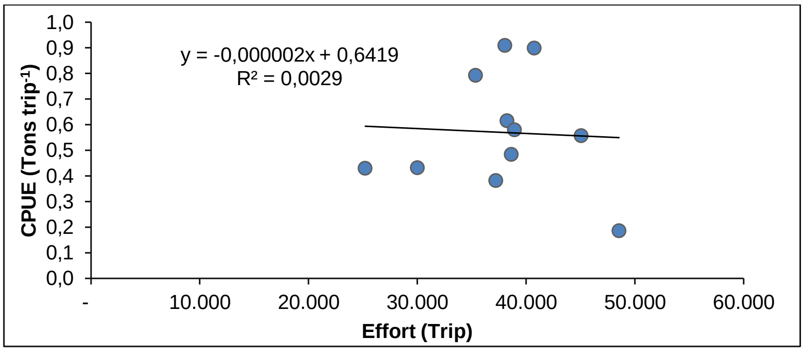

Figure 6. Linear equations of CPUE and effort *Thunnus albacares.*

The relationship between CPUE and effort in Figure 6 shows that the value of the estimation parameter for tuna fish is obtained by an intercept (a) = 0.6419 and a slope (b) = -0.000002 so as to form the Schaefer linear equation CPUE = -0.000002x + 0.6419. This relationship can be interpreted that by catching x units per year, it will reduce the CPUE value by 0.000002 tons per year. The conditions described in the linear equation produce a value of R^2 = 0.0029 which means that around 0.29% the CPUE is influenced

by the effort. Thus, the R^2 value indicate that the influence of the variables used in this model is not strong.

Maximum Sustainable Yield (MSY) and Economic Maximum Sustainable Yield (EMSY) calculation data for *T. albacares* in FMA-RI 714 using the Schaefer Linear method are presented in Table 5. The results of biological analysis using the Schaefer Linear model approach can produce an MSY value of 54,027 tons with a standard effort/EMSY of 168,332 trips.

Table 5

MSY and EMSY *Thunnus albacares* Based on Schaefer linear model calculations

Year	*Number of catches (Tons)*	*Total standard effort*	*CPUE (Schaefer)*
I	*Yi*	*X*	*Y*
2008	10,848.5	25,213	0.4303
2009	14,213.2	37,215	0.3819
2010	9,063.9	48,538	0.1867
2011	23,513.3	38,251	0.6147
2012	25,093.6	45,057	0.5569
2013	36,677.5	40,768	0.8997
2014	18,736.9	38,637	0.4849
2015	12,969.1	30,022	0.4320
2016	22,570.3	38,961	0.5793
2017	28,041.4	35,388	0.7924
2018	34,605.9	38,082	0.9087
Total	236,333.9	416,131	6.2676
Average	21,484.9	37,830	0.5697
	Intercept a		0.6419
	Slope b		-0.000002
	MSY Schaefer: -a^2/4b		54,027
	EMSY Schaefer: -a/2b		168,332
	Total Allowable Catch (TAC) 80% MSY		43,221.80

Based on linear model calculations, biological saturation yields have not occurred in *T. albacares* from FMA RI-714, which is indicated by actual catches that are not close to their sustainable potential (MSY). This is evidenced by the actual catch in 2018 which reached 34,605.9 tonnes, not yet exceeding the potential TAC of 80% of the MSY value (43,221.80 tonnes). The sustainable potential curve (MSY) of *T. albacares* can be seen in Figure 7.

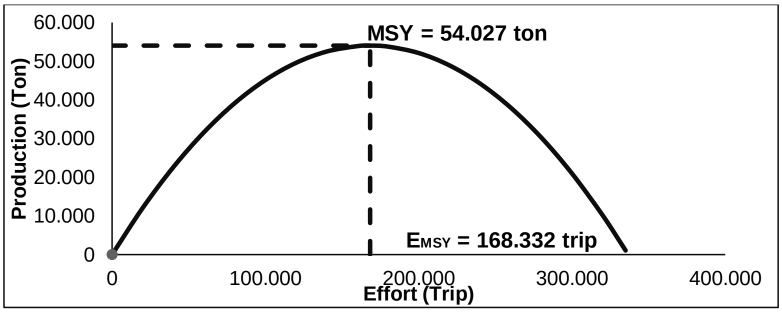

Figure 7. Stock equilibrium curve (MSY) of *Thunnus albacares* in FMA RI-714.

Conclusions. The biological aspects of *T. albacares* in Maluku waters show that the growth pattern of tuna is isometric. The exploitation of *T. albacares* is in a condition where

production continues to increase with a low level of fishing gear selectivity, therefore regulating and supervising the fishing gear are required.

Conflict of interest. The author declares no conflict of interest.

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Authors:
Ratna Suharti, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: r_suharti@yahoo.com
Mira Maulita, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: maulita.stp@gmail.com
Firman Setiawan, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: firmansetiawan001@gmail.com
Dadan Zulkifli, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: belfyludaputri@gmail.com
Basuki Rachmad, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: basukibye248@gmail.com
Maman Hermawan, Faculty of Fishing Technology, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: mhermawan60@gmail.com

Mantani Sayuri, Department of Ships Navigation, Japan Agency of Maritime Education and Training for Seafarers, Marine Technical College, Ashiya City 659-0026, Hyogo, Japan, e-mail: mantani-s6ea@jmets.ac.jp
Erick Nugraha, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: nugraha_eriq1@yahoo.co.id

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Eni Kovacs <ek.bioflux@gmail.com>
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Status of the *Thunnus albacares* fishery in the Fisheries Management Area (FMA) 714, Banda Sea, Indonesia

[1]Ratna Suharti, [1]Mira Maulita, [1]Firman Setiawan, [1]Basuki Rachmad, [1]Dadan Zulkifli, [2]Mantani Sayuri, [3]Maman Hermawan, [3]Erick Nugraha

[1] Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, South Jakarta, Indonesia; [2] Department of Ships Navigation, Marine Technical College, Hyogo, Japan; [3] Faculty of Fishing Technology, Jakarta Technical University of Fisheries, South Jakarta, Indonesia. Corresponding author: E. Nugraha, nugraha_eriq1@yahoo.co.id

Abstract. The Banda Sea is a potential fishing area for large pelagic fish, especially tuna. Exploitation of this resource is carried out by various forms of fishing activities, including purse seine, pole and line, longline tuna, and handline tuna. In addition, the utilization of fish resources in FMA RI 714 is still dominated by small-scale fishermen using vessels <5 GT. Based on the large potential and condition of the available large pelagic fish resources, it is necessary to study the status of large pelagic fisheries, especially tuna in the Maluku region. This study aimed to examine the biological aspects of tuna and the fisheries management. The research was carried out from 4 March to 25 May 2021 in the Maluku Sea. This study used a survey method, namely by observing in the field the observed fish samples. Determination of the location and fishing gear was carried out by purposive sampling, while the determination of respondents was carried out by accidental sampling. The results showed that the growth pattern of *Thunnus albacares* was isometric. The size of the first caught in the purse seine for *T. albacares* was 39.09 cm Fork Length. In Fisheries Management Area of Republic Indonesia (FMA RI) 714, the actual production and tuna fishing effort shows that its utilization did not reach the maximum sustainable level and economically, tuna fishing did not yet reach the maximum profit value so that its utilization can still be increased.
Key Words: yellowfin tuna, Banda Sea, length of first caught, CPUE.

Introduction. The Banda Sea is located in the Eastern Indonesia Region and is included in the waters of the West Pacific Ocean, being bordered by the Indian Ocean (Firdaus 2018). The Banda Sea has also become a potential tuna fishing area in Maluku Province (Satrioajie et al 2018; Tangke et al 2011). Exploitation of tuna resources is carried out in various forms of fishing activities, including purse seiner, pole and liner, longliner and tuna handliner (Tauda et al 2021; Khan et al 2018; Widodo & Nugraha 2009). Tuna resources are spread throughout almost all Indonesian waters, from western Indonesian waters (Indian Ocean) to Eastern Indonesia (Banda Sea and North Irian Jaya) (Chodrijah & Nugraha 2013). The waters of Eastern Indonesia are known as sources for the production of tuna and skipjack, which are commonly called tuna in Indonesia (Manurung 2016). Banda Sea is a fishing ground for large pelagic fish in eastern Indonesia (Hidayat et al 2014).

Based on the results of a study of tuna stocks by the Western and Central Pacific Fisheries Commission (WCPFC) in 2012, it was reported that stocks of yellowfin tuna (*Thunnus albacares*) were not overfished, while bigeye tuna (*Thunnus obesus*) experienced overfishing (Post & Squires 2020; Hare et al 2020; Widodo et al 2015). The utilization of fish resources in WPP 714 is still dominated by small-scale fishermen using vessels <5GT (JICA 2010; Adam 2016), due to the availability of large pelagic fish resources. Therefore, monitoring the status of large pelagic fisheries in the Maluku region, especially those targeting tuna, is required.

This study aimed to examine several aspects of *T. albacares*: a) biological aspects, including length-weight relationship, b) *T. albacares* exploitation characteristics, including production trends, fishing effort, fishing grounds, fishing season, fishing gear and CPUE and c) management of tuna resources, which includes calculating the catch rate, Maximum Sustainable Yield, Maximum Economic Yield, and Total Allowable Catches of *T. albacares* in the Maluku region.

Material and Method

The research was conducted for 90 days, from March 4 to May 25, 2021, in the Banda Sea, by focusing on fishing ports with high tuna landing potential. Data collection was carried out at several sampling points, as shown in Figure 1.

Figure 1. Map of research locations.

Tools and materials. The tools and materials used in this study are as follows: rulers, tape measure, digital scales, cameras, stationery, identification labels, and some samples of tuna.

Methods of data collection. In this study, the applied survey method was the field observation. Determination of the location and fishing gear was carried out by purposive sampling, namely collecting data deliberately according to the desired conditions (Tongco 2007). Meanwhile, the determination of respondents was carried out by accidental sampling, namely the accidental determination of tuna fishermen (Siburian et al 2020). Data collection for *T. albacares* sampling was carried out using the simple random sampling method, by measuring the specimens' length and weight of 10% of the total catch (Mous et al 1995). Secondary data are time series of catches and fishing effort for 5 to 10 years, from the relevant agencies.

Data collection. Primary data collection was carried out by direct observation and measurement (Hardani et al 2020) of landed *T. albacares*. The data collected included: fork length, total weight, sex, and GML. Secondary data needed is in the form of periodic data (time series) of catches and fishing effort for the last 10 years obtained from the Maritime Affairs and Fisheries Service of Maluku Province.

Data analysis

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

Length-weight relationship. The relationship between length and weight uses a linear allometric model. This model is used to calculate parameters a and b through measurements of length and weight (Brinkman 1993; Nugraha et al 2020; Effendie 1979):

$$W = aL^b$$

Where:
W - individual weights of fish (grams);
L - fork length fish (cm);
a - Intercept (intersection of the curve of the relationship of the length of the weight with the y-axis);
b - slope.

To determine the values of a and b, a linear regression analysis, based on the logarithm of the formula above. The linear equation becomes:

$$L_n\ W_{(i)} = L_n\ q + bL_n$$

Then a simple linear equation can be made (Agustian et al 2021; Muhsoni 2019):

$$Y = a + bX_{(i)}$$

Where:
Y - L_n W;
X - Ln;
a' - antilog intercept;
b - slope.

The coefficients of determination and correlation can also be determined through equations.

In this analysis of weight length relationships, what needs to be considered is the value of b which can be interpreted as follows:

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) (Perangin-angin et al 2015).

To determine the growth pattern, Bailey's t-$_{test}$ was needed (Thomas 2013; Nair et al 2015). The t-$_{test}$ was run to determine significant differences from the isometric value (b = 3) with significant level at 5% ($P < 0.05$). The formula of Bailey's t-$_{test}$ is as follows (Fauziyah et al 2021):

$$t_s = \left|\frac{3 - b}{Sb}\right|$$

Where:
t_s - Bailey's t-$_{test}$;
b - the slope of the linear regression;
Sb - standard error of the b coefficients.

The correlation coefficient (r) to see the closeness of the relationship between length and weight is obtained from the formula bellows (Nurhayati et al 2016).

$$r^2 = \frac{(\sum X_i Y_i)^2}{(\sum X_i^2)(\sum Y_i^2)}$$

$$r = \sqrt{r^2}$$

Where:
r - correlation coefficient is an abstract measure of the degree of closeness of the relationship between x and y ($-1 < r < 1$);
1 - there is a close and positive relationship;
-1 - there is a close and negative relationship;
0 - there is no close relationship.

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

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

Where:
SL - estimated value;
a – intercept;
b – slope.

The value of Lc was obtained by plotting the percentage of the cumulative frequency of fish caught with the standard length, where the intersection point between the 50% cumulative frequency curve is the length when 50% of the fish are caught (Diningrum et al 2019). The value of Lc can be calculated through the formula (Sparre et al 1989):

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

Catch Per Unit Effort (CPUE). Catch data and fishing effort were obtained, then tabulated to determine the value of CPUE. The fishing effort can be expressed as the number of operating days or months, the number of fishing trips or the number of fleets carrying out fishing operations. In this study the fishing effort (effort) used is expressed as the number of trips. The formula that can be used to determine the CPUE value is as follows (Imron et al 2022):

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

Where:
$CPUE_i$ - catch per unit of fishing effort for the period i (tons $trip^{-1}$);
$Catch_i$ - catch for the period i (tons);
$Effort_i$ - fishing effort for the period i (trip).

Standardization of fishing gear. According to Ardelia et al (2018), standardization is done by finding the Fishing Power Index (FPI) value of each fishing gear. The fishing gear used as standard has an FPI value equal to one, while the FPI value for other fishing gear is obtained from the CPUE of the other fishing gear divided by the CPUE of the standard fishing gear. The Gulland formula for calculating FPI is as follows (Gulland 1983):

$$RFP_i = \frac{Ci/Ei}{Cs/Es}$$

Where:
RFP_i - relative fishing power factor of the i^{th} fishing unit;
C_i - the number of catches of the i^{th} fishing unit;
C_s - the standard number of catches of the fishing unit type;
E_i - the effort of catching with the i^{th} fishing unit;
E_s - the standard effort of catching with the fishing unit type.

After obtaining the RFP_i value, the standardized fishing effort is calculated using the formula:

$$\text{Standard effort} = \sum(FPI_i \times effort_i)$$

Production surplus model. The purpose of using the Production Surplus Model is to determine the level of optimal effort, corresponding to a maximum sustainable catch without affecting long-term stock productivity which we usually call Maximum Sustainable Yield (Sari & Nurainun 2022).

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

$$CPUE = \frac{Y}{f} = \frac{Y(i)}{f(i)}, i = 1, 2, ... n$$

Where:
Y(i) - catch for the period i, I = 1, 2, ...n;
f(i) - fishing effort for the period i.

Determining the value of a (intercept) and b (slope) requires linear regression off(i) to Y(i)/f(i). After the a and b values are obtained, the optimum effort (f_{MSY}) and Maximum Sustainable Yield (MSY) can be calculated by the formula (Kartini et al 2021):

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

The level of utilization of fish resources is a fraction of the maximum Sustainable Yield (MSY) (Zahra et al 2019):
:

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

Where:
Ci - number of fish caught in year I;
MSY - maximum sustainable yield.

Results and discussion

Distribution of T. albacares length frequency. Based on observations of 339 samples of *T. albacares*, the shortest length was 31 cm and the longest is 126 cm. The length frequency distribution is presented in Figure 2.

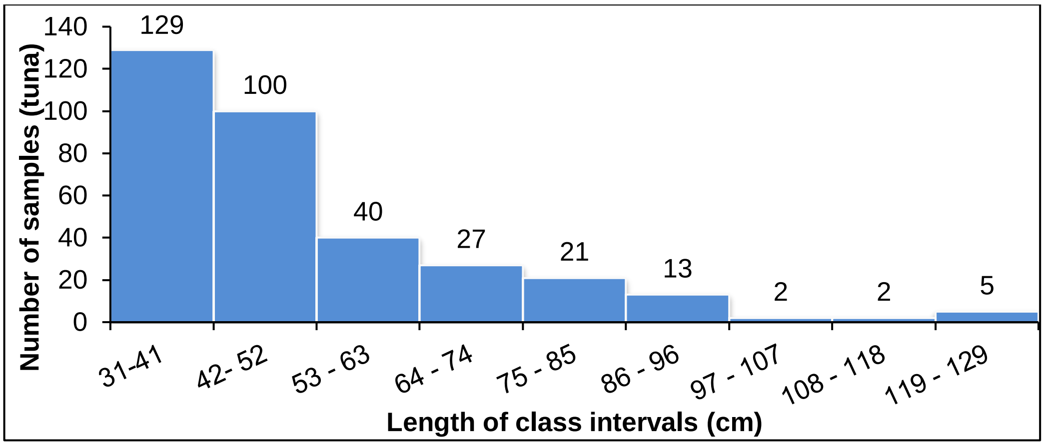

Figure 2. Length frequency distribution of *Thunnus albacares.*

The modal class interval was 31-41 cm: many small fish are caught by trolling liner and purse seiner.

The relationship between length and weight of T. albacares. The relationship between length and weight is presented on the graph, according to the characteristics of the fish growth pattern, as shown in Figure 3.

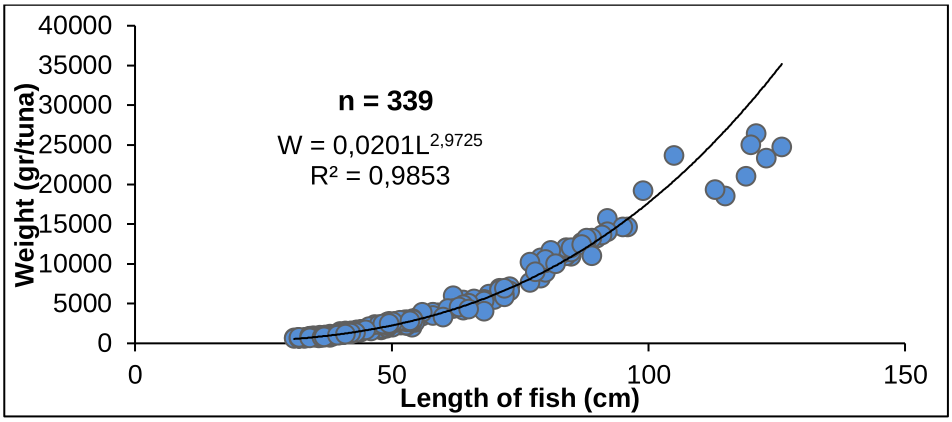

Figure 3. Length-weight relationship of *Thunnus albacares.*

From the results of the analysis of the length-weight relationship of the species *T. albacares*, the following equation was determined: $W=0.0201\ L^{2.9725}$, with a value of b=2.9725. Then a t_{-test} was carried out on the value of b at a 95% confidence interval and obtained $t_{count}<t_{table}$ ($t_{count}=1.393$; $t_{table}=1.967$), therefore H_0 was accepted, which means that the increase rates in length and weight are not significantly different, so that it can be said that the increase in length is proportional to the increase in weight (isometric).

From the results of the t_{test}, it is necessary to carry out further calculations to obtain a new *T. albacares* length-weight relationship equation, by substituting the values of $\bar{Y}$ and $\bar{X}$ using $\bar{Y} = a'-3\bar{X}$, namely $W=0.018055\ L^3$. Calculation of the growth pattern was carried out using the $t_{\ test}$ ($t_{count}=0.05$), at a 95% confidence interval (α=0.05), producing a coefficient of determination (R^2) of 0.9928 and a correlation coefficient (r) close to 1. This shows that an increase in the length affects the weight gain, meaning that the correlation or relationship between length and fish weight is strong and positive.

Length at first capture (Lc). Calculation of the size of the first catch of *T. albacares* was carried out using data on the length and number of fish caught in purse seine catches. Based on the observation of the 70 caught specimens, the Lc was 39.55 cm as it can be seen in Figure 4.

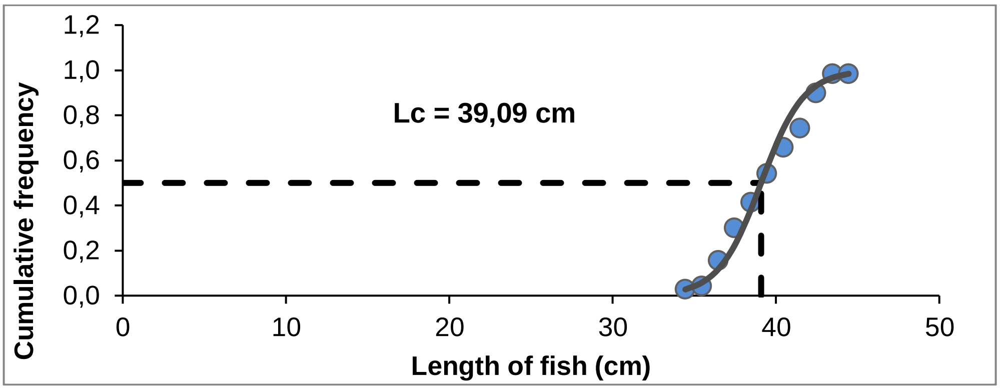

Figure 4. Length at first capture of *Thunnus albacares* on purse seine.

Fishing ground. The dominant fishing grounds for fishermen in the province of Maluku are located in the Banda Sea (FMA RI 714). These areas are usually approached by *T. albacares* due to environmental factors, food availability and they are also spawning and egg-laying areas. The highest catch occurs at the beginning of the East season, also called the harvest season, from October to December. The lean season is from May to July, the western season is from December to January and the transition season is from April to May. The catches obtained depend on the season, currents and wind, which might be obstacles for going to sea and succeeding to make catches.

Stock status in Fishery Management Area - Republic of Indonesia (FMA-RI 714)

CPUE and MSY T. albacares. In Table 2 it can be seen the production data and fishing effort of *T. albacares* in FMA RI-714 by hand liner, troll liner, purse seiner, and the pole and liner.

Table 2

FMA RI-714 production and fishing effort

Year	*Production (tons)*					*Trip*			
	Purse seiner	*Trolling liner*	*Hand liner*	*Pole and liner*	*Total*	*Purse seiner*	*Trolling liner*	*Hand liner*	*Pole and liner*
2008	3,868.71	3,813.07	39.29	3,127.51	10,848.57	23,419	427,899	201	8,546
2009	3,997.51	4,961.22	1,500.39	3,754.16	14,213,28	21,373	392,497	248,406	9,457
2010	3,982.52	1,335.69	993.14	2,752.55	9,063.90	43,622	474,562	311,339	8,429
2011	4,710.08	9,739.77	2,424.13	6,639.34	23,513.32	35,888	433,171	191,396	7,641
2012	5,169.07	14,869.32	1,017.65	4,037.61	25,093.65	42,027	432,897	226,447	10,617
2013	19,288.48	10,298.59	3,125.72	3,964.70	36,677.49	32,010	484,526	186,753	10,646
2014	6,094.66	3,863.20	4,381.17	4,397.88	18,736.91	39,017	141,506	293,614	7,797
2015	4,505.92	381.21	2,587.83	5,494.17	12,969.12	34,787	247,776	85,352	8,922
2016	10,159.34	879.72	3,675.05	7,856.27	22,570.37	41,596	291,150	204,868	8,657
2017	13,102.44	1,476.79	5,140.45	8,321.75	28,041.43	38,453	226,620	191,767	8,125
2018	13,661.33	2,145.53	6,076.82	12,722.25	34,605.93	48,078	255,188	157,874	8,698

There are differences in fishing productivity between hand liner, troll liner, purse seiner, and pole and liner, it is necessary to standardize productivity, to obtain the Fishing Power Index (FPI) as can be seen in the Table 3.

Table 3

Productivity and fishing power index (FPI) in *Thunnus albacares*

Year	*Productivity (tons trip^{-1})*			
	Purse seine	*Trolling line*	*Hand line*	*Pole and line*
2008	0.1652	0.0089	0.1955	0.3660
2009	0.1870	0.0126	0.0060	0.3970
2010	0.0913	0.0028	0.0032	0.3265
2011	0.1312	0.0225	0.0127	0.8689
2012	0.1230	0.0343	0.0045	0.3803
2013	0.6026	0.0213	0.0167	0.3724
2014	0.1562	0.0273	0.0149	0.5641
2015	0.1295	0.0015	0.0303	0.6158
2016	0.2442	0.0030	0.0179	0.9075
2017	0.3407	0.0065	0.0268	1.0242
2018	0.2841	0.0084	0.0385	1.4627
Average	0.2232	0.0136	0.0334	0.6623
CPUE	0.2232	0.0136	0.0334	0.6623
FPI	0.3370	0.0204	0.0504	1

Based on Table 3, the huhate is used as standard fishing gear, because its productivity is larger than other fishing gear. Furthermore, the standardization process, resulting from the multiplication of the FPI with the number of fishing gears, produces the standard effort values presented in Table 4.

Table 4

Standardization of *Thunnus albacares* catching efforts

Year	*Purse seiner*	*Trolling liner*	*Hand liner*	*Pole and liner*	*Total effort standard*	*CPUE (ton trip^{-1})*
2008	7,892	8,765	10	8,546	25,213	0.4303
2009	7,203	8,040	12,515	9,457	37,215	0.3819
2010	14,701	9,721	15,686	8,429	48,538	0.1867

Year	*Purse seiner*	*Trolling liner*	*Hand liner*	*Pole and liner*	*Total effort standard*	*CPUE (ton trip⁻¹)*
2011	12,094	8,873	9,643	7,641	38,251	0.6147
2012	14,163	8,868	11,409	10,617	45,057	0.5569
2013	10,787	9,925	9,409	10,646	40,768	0.8997
2014	13,149	2,899	14,793	7,797	38,637	0.4849
2015	11,723	5,076	4,300	8,922	30,022	0.4320
2016	14,018	5,964	10,322	8,657	38,961	0.5793
2017	12,959	4,642	9,662	8,125	35,388	0.7924
2018	16,202	5,227	7,954	8,698	38,082	0.9087

The effort and yield data shown in Table 3 will produce CPUE fluctuations every year as shown in Figure 5.

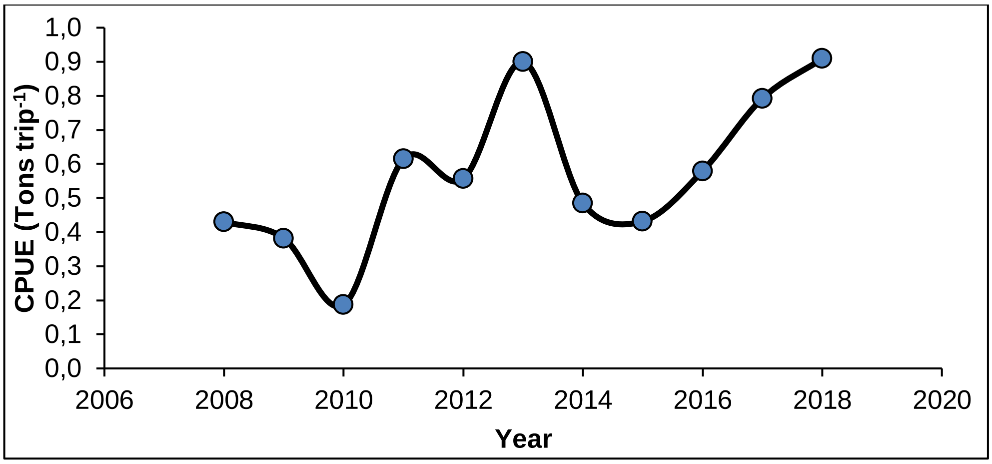

Figure 5*. Thunnus albacares* CPUE fluctuation in FMA-RI 714.

From Figure 5 it can be concluded that 2013 was the highest CPUE point. Even though the CPUE decreased from 2014 to 2015, the conditions did not disturb the sustainability of tuna fishing activities in FMA-RI 714.

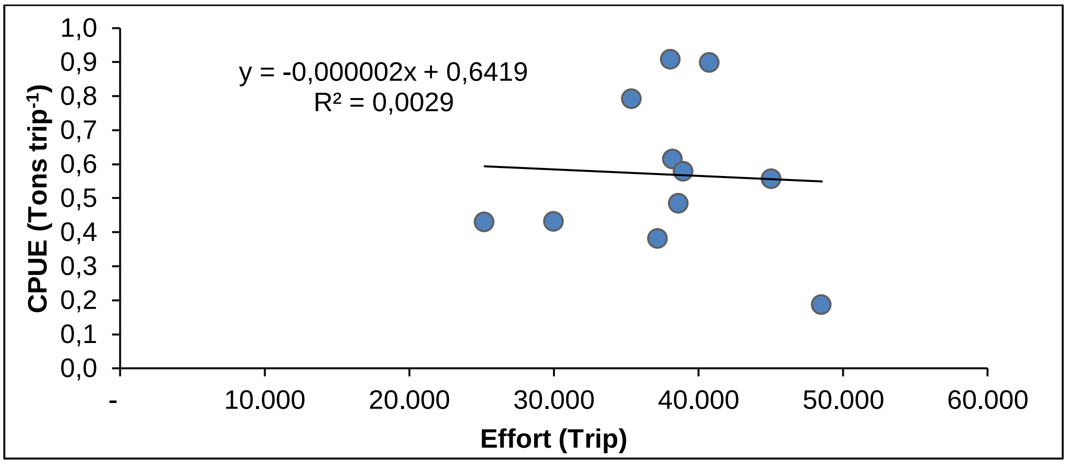

Figure 6. Linear equations of CPUE and effort *Thunnus albacares.*

The relationship between CPUE and effort in Figure 6 shows that the value of the estimation parameter for tuna fish is obtained by an intercept (a) = 0.6419 and a slope (b) = -0.000002 so as to form the Schaefer linear equation CPUE = -0.000002x + 0.6419. This relationship can be interpreted that by catching x units per year, it will reduce the CPUE value by 0.000002 tons per year. The conditions described in the linear equation produce a value of R^2 = 0.0029 which means that around 0.29% the CPUE is influenced

by the effort. Thus, the R^2 value indicate that the influence of the variables used in this model is not strong.

Maximum Sustainable Yield (MSY) and Economic Maximum Sustainable Yield (EMSY) calculation data for *T. albacares* in FMA-RI 714 using the Schaefer Linear method are presented in Table 5. The results of biological analysis using the Schaefer Linear model approach can produce an MSY value of 54,027 tons with a standard effort/EMSY of 168,332 trips.

Table 5

MSY and EMSY *Thunnus albacares* Based on Schaefer linear model calculations

Year	*Number of catches (Tons)*	*Total standard effort*	*CPUE (Schaefer)*
I	*Yi*	*X*	*Y*
2008	10,848.5	25,213	0.4303
2009	14,213.2	37,215	0.3819
2010	9,063.9	48,538	0.1867
2011	23,513.3	38,251	0.6147
2012	25,093.6	45,057	0.5569
2013	36,677.5	40,768	0.8997
2014	18,736.9	38,637	0.4849
2015	12,969.1	30,022	0.4320
2016	22,570.3	38,961	0.5793
2017	28,041.4	35,388	0.7924
2018	34,605.9	38,082	0.9087
Total	236,333.9	416,131	6.2676
Average	21,484.9	37,830	0.5697
Intercept a			0.6419
Slope b			-0.000002
MSY Schaefer: -a^2/4b			54,027
EMSY Schaefer: -a/2b			168,332
Total Allowable Catch (TAC) 80% MSY			43,221.80

Based on linear model calculations, biological saturation yields have not occurred in *T. albacares* from FMA RI-714, which is indicated by actual catches that are not close to their sustainable potential (MSY). This is evidenced by the actual catch in 2018 which reached 34,605.9 tonnes, not yet exceeding the potential TAC of 80% of the MSY value (43,221.80 tonnes). The sustainable potential curve (MSY) of *T. albacares* can be seen in Figure 7.

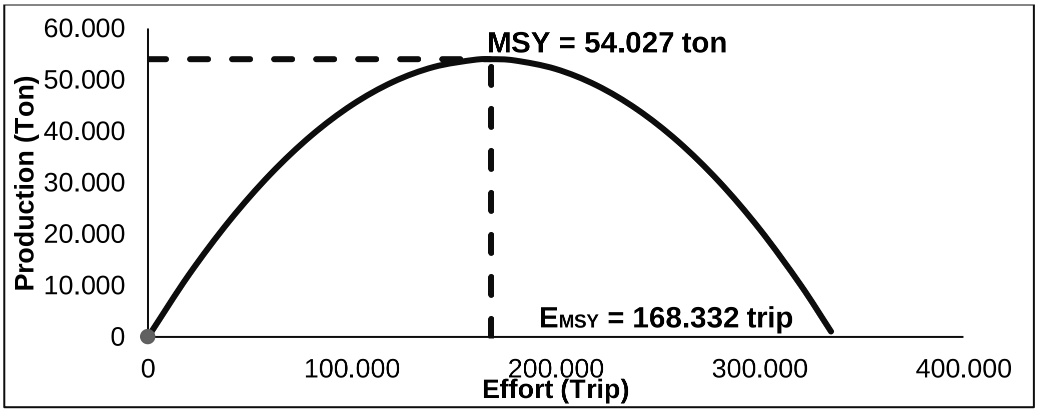

Figure 7. Stock equilibrium curve (MSY) of *Thunnus albacares* in FMA RI-714.

Conclusions. The biological aspects of *T. albacares* in Maluku waters show that the growth pattern of tuna is isometric. The exploitation of *T. albacares* is in a condition where

production continues to increase with a low level of fishing gear selectivity, therefore regulating and supervising the fishing gear are required.

Conflict of interest. The author declares no conflict of interest.

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Authors:
Ratna Suharti, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: r_suharti@yahoo.com
Mira Maulita, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: maulita.stp@gmail.com
Firman Setiawan, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: firmansetiawan001@gmail.com
Dadan Zulkifli, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: belfyludaputri@gmail.com
Basuki Rachmad, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: basukibye248@gmail.com
Maman Hermawan, Faculty of Fishing Technology, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: mhermawan60@gmail.com
Mantani Sayuri, Department of Ships Navigation, Japan Agency of Maritime Education and Training for Seafarers, Marine Technical College, Ashiya City 659-0026, Hyogo, Japan, e-mail: mantani-s6ea@jmets.ac.jp
Erick Nugraha, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: nugraha_eriq1@yahoo.co.id

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erick nugraha <nugraha_eriq1@yahoo.co.id>
Kepada: Eni Kovacs

Kam, 6 Apr jam 07.07

Dear, Dr. Eni
I send you notification letter.

Thank You.

Erick Nugraha
Jakarta, Indonesia

> Tampilkan pesan asli

Unduh semua lampiran sebagai file zip

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STATEMENT LETTER

Hereby we declare our article with the title:

Status of the *Thunnus albacares* fishery in the Fisheries Management Area (FMA) 714, Banda Sea, Indonesia

It has gone through several editing processes and we agreed to publish it.
Thank you.

Name of the authors:

Author,

Ratna Suharti | Mira Maulita | Maman Hermawan

Firman Setiawan | Basuki Rachmad | Dadan Zulkifli

Mantani Sayuri | Erick Nugraha

Date: April, 6th 2023

Status of the *Thunnus albacares* fishery in the Fisheries Management Area (FMA) 714, Banda Sea, Indonesia

[1]Ratna Suharti, [1]Mira Maulita, [1]Firman Setiawan, [1]Basuki Rachmad, [1]Dadan Zulkifli, [2]Mantani Sayuri, [3]Maman Hermawan, [3]Erick Nugraha

[1] Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, South Jakarta, Indonesia; [2] Department of Ships Navigation, Marine Technical College, Hyogo, Japan; [3] Faculty of Fishing Technology, Jakarta Technical University of Fisheries, South Jakarta, Indonesia. Corresponding author: E. Nugraha, nugraha_eriq1@yahoo.co.id

Abstract. The Banda Sea is a potential fishing area for large pelagic fish, especially tuna. Exploitation of this resource is carried out by various forms of fishing activities, including purse seine, pole and line, longline tuna, and handline tuna. In addition, the utilization of fish resources in FMA RI 714 is still dominated by small-scale fishermen using vessels <5 GT. Based on the large potential and condition of the available large pelagic fish resources, it is necessary to study the status of large pelagic fisheries, especially tuna in the Maluku region. This study aimed to examine the biological aspects of tuna and the fisheries management. The research was carried out from 4 March to 25 May 2021 in the Maluku Sea. This study used a survey method, namely by observing in the field the observed fish samples. Determination of the location and fishing gear was carried out by purposive sampling, while the determination of respondents was carried out by accidental sampling. The results showed that the growth pattern of *Thunnus albacares* was isometric. The size of the first caught in the purse seine for *T. albacares* was 39.09 cm Fork Length. In Fisheries Management Area of Republic Indonesia (FMA RI) 714, the actual production and tuna fishing effort shows that its utilization did not reach the maximum sustainable level and economically, tuna fishing did not yet reach the maximum profit value so that its utilization can still be increased.
Key Words: yellowfin tuna, Banda Sea, length of first caught, CPUE.

Introduction. The Banda Sea is located in the Eastern Indonesia Region and is included in the waters of the West Pacific Ocean, being bordered by the Indian Ocean (Firdaus 2018). The Banda Sea has also become a potential tuna fishing area in Maluku Province (Satrioajie et al 2018; Tangke et al 2011). Exploitation of tuna resources is carried out in various forms of fishing activities, including purse seiner, pole and liner, longliner and tuna handliner (Tauda et al 2021; Khan et al 2018; Widodo & Nugraha 2009). Tuna resources are spread throughout almost all Indonesian waters, from western Indonesian waters (Indian Ocean) to Eastern Indonesia (Banda Sea and North Irian Jaya) (Chodrijah & Nugraha 2013). The waters of Eastern Indonesia are known as sources for the production of tuna and skipjack, which are commonly called tuna in Indonesia (Manurung 2016). Banda Sea is a fishing ground for large pelagic fish in eastern Indonesia (Hidayat et al 2014).

Based on the results of a study of tuna stocks by the Western and Central Pacific Fisheries Commission (WCPFC) in 2012, it was reported that stocks of yellowfin tuna (*Thunnus albacares*) were not overfished, while bigeye tuna (*Thunnus obesus*) experienced overfishing (Post & Squires 2020; Hare et al 2020; Widodo et al 2015). The utilization of fish resources in WPP 714 is still dominated by small-scale fishermen using vessels <5GT (JICA 2010; Adam 2016), due to the availability of large pelagic fish resources. Therefore, monitoring the status of large pelagic fisheries in the Maluku region, especially those targeting tuna, is required.

This study aimed to examine several aspects of *T. albacares*: a) biological aspects, including length-weight relationship, b) *T. albacares* exploitation characteristics, including production trends, fishing effort, fishing grounds, fishing season, fishing gear and CPUE and c) management of tuna resources, which includes calculating the catch rate, Maximum Sustainable Yield, Maximum Economic Yield, and Total Allowable Catches of *T. albacares* in the Maluku region.

Material and Method

The research was conducted for 90 days, from March 4 to May 25, 2021, in the Banda Sea, by focusing on fishing ports with high tuna landing potential. Data collection was carried out at several sampling points, as shown in Figure 1.

Figure 1. Map of research locations.

Tools and materials. The tools and materials used in this study are as follows: rulers, tape measure, digital scales, cameras, stationery, identification labels, and some samples of tuna.

Methods of data collection. In this study, the applied survey method was the field observation. Determination of the location and fishing gear was carried out by purposive sampling, namely collecting data deliberately according to the desired conditions (Tongco 2007). Meanwhile, the determination of respondents was carried out by accidental sampling, namely the accidental determination of tuna fishermen (Siburian et al 2020). Data collection for *T. albacares* sampling was carried out using the simple random sampling method, by measuring the specimens' length and weight of 10% of the total catch (Mous et al 1995). Secondary data are time series of catches and fishing effort for 5 to 10 years, from the relevant agencies.

Data collection. Primary data collection was carried out by direct observation and measurement (Hardani et al 2020) of landed *T. albacares*. The data collected included: fork length, total weight, sex, and GML. Secondary data needed is in the form of periodic data (time series) of catches and fishing effort for the last 10 years obtained from the Maritime Affairs and Fisheries Service of Maluku Province.

Data analysis

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

Length-weight relationship. The relationship between length and weight uses a linear allometric model. This model is used to calculate parameters a and b through measurements of length and weight (Brinkman 1993; Nugraha et al 2020; Effendie 1979):

$$W = aL^b$$

Where:
W - individual weights of fish (grams);
L - fork length fish (cm);
a - Intercept (intersection of the curve of the relationship of the length of the weight with the y-axis);
b - slope.

To determine the values of a and b, a linear regression analysis, based on the logarithm of the formula above. The linear equation becomes:

$$L_n\ W_{(i)} = L_n\ q + bL_n$$

Then a simple linear equation can be made (Agustian et al 2021; Muhsoni 2019):

$$Y = a + bX_{(i)}$$

Where:
Y - L_n W;
X - Ln;
a' - antilog intercept;
b - slope.

The coefficients of determination and correlation can also be determined through equations.

In this analysis of weight length relationships, what needs to be considered is the value of b which can be interpreted as follows:

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) (Perangin-angin et al 2015).

To determine the growth pattern, Bailey's t_{test} was needed (Thomas 2013; Nair et al 2015). The t_{test} was run to determine significant differences from the isometric value (b = 3) with significant level at 5% ($P < 0.05$). The formula of Bailey's t_{test} is as follows (Fauziyah et al 2021):

$$t_s = \left|\frac{3 - b}{Sb}\right|$$

Where:
t_s - Bailey's t_{test};
b - the slope of the linear regression;
Sb - standard error of the b coefficients.

The correlation coefficient (r) to see the closeness of the relationship between length and weight is obtained from the formula bellows (Nurhayati et al 2016).

$$r^2 = \frac{(\sum X_i Y_i)^2}{(\sum X_i^2)(\sum Y_i^2)}$$

$$r = \sqrt{r^2}$$

Where:
r - correlation coefficient is an abstract measure of the degree of closeness of the relationship between x and y ($-1 < r < 1$);
1 - there is a close and positive relationship;
-1 - there is a close and negative relationship;
0 - there is no close relationship.

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

$$SL = \frac{1}{a + \exp\,(a - b\,L)}$$

Where:
SL - estimated value;
a – intercept;
b – slope.

The value of Lc was obtained by plotting the percentage of the cumulative frequency of fish caught with the standard length, where the intersection point between the 50% cumulative frequency curve is the length when 50% of the fish are caught (Diningrum et al 2019). The value of Lc can be calculated through the formula (Sparre et al 1989):

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

Catch Per Unit Effort (CPUE). Catch data and fishing effort were obtained, then tabulated to determine the value of CPUE. The fishing effort can be expressed as the number of operating days or months, the number of fishing trips or the number of fleets carrying out fishing operations. In this study the fishing effort (effort) used is expressed as the number of trips. The formula that can be used to determine the CPUE value is as follows (Imron et al 2022):

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

Where:
$CPUE_i$ - catch per unit of fishing effort for the period i (tons trip^{-1});
$Catch_i$ - catch for the period i (tons);
$Effort_i$ - fishing effort for the period i (trip).

Standardization of fishing gear. According to Ardelia et al (2018), standardization is done by finding the Fishing Power Index (FPI) value of each fishing gear. The fishing gear used as standard has an FPI value equal to one, while the FPI value for other fishing gear is obtained from the CPUE of the other fishing gear divided by the CPUE of the standard fishing gear. The Gulland formula for calculating FPI is as follows (Gulland 1983):

$$RFP_i = \frac{Ci/Ei}{Cs/Es}$$

Where:
RFP_i - relative fishing power factor of the ith fishing unit;
C_i - the number of catches of the ith fishing unit;
C_s - the standard number of catches of the fishing unit type;
E_i - the effort of catching with the ith fishing unit;
E_s - the standard effort of catching with the fishing unit type.

After obtaining the RFP_i value, the standardized fishing effort is calculated using the formula:

$$\text{Standard effort} = \sum(FPI_i \times effort_i)$$

Production surplus model. The purpose of using the Production Surplus Model is to determine the level of optimal effort, corresponding to a maximum sustainable catch without affecting long-term stock productivity which we usually call Maximum Sustainable Yield (Sari & Nurainun 2022).

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

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

Where:
Y(i) - catch for the period i, I = 1, 2, ...n;
f(i) - fishing effort for the period i.

Determining the value of a (intercept) and b (slope) requires linear regression off(i) to Y(i)/f(i). After the a and b values are obtained, the optimum effort (f_{MSY}) and Maximum Sustainable Yield (MSY) can be calculated by the formula (Kartini et al 2021):

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

The level of utilization of fish resources is a fraction of the maximum Sustainable Yield (MSY) (Zahra et al 2019):
:

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

Where:
Ci - number of fish caught in year I;
MSY - maximum sustainable yield.

Results and discussion

Distribution of T. albacares length frequency. Based on observations of 339 samples of *T. albacares*, the shortest length was 31 cm and the longest is 126 cm. The length frequency distribution is presented in Figure 2.

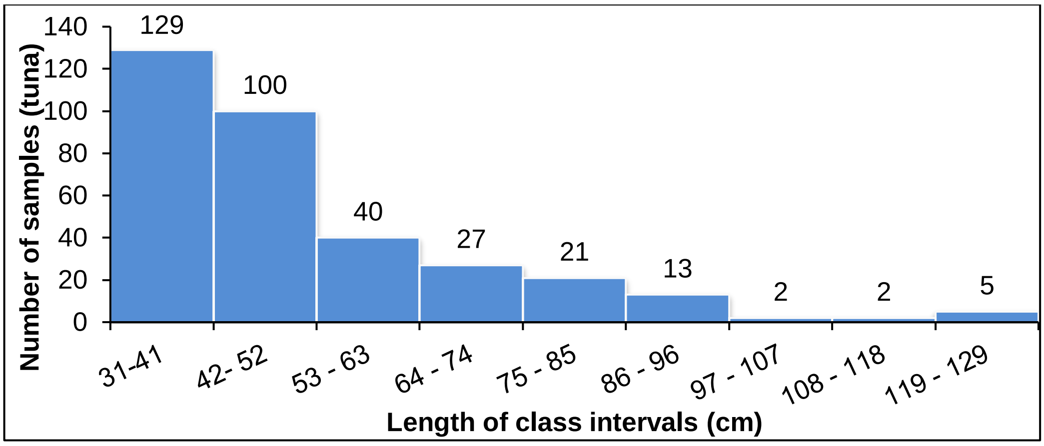

Figure 2. Length frequency distribution of *Thunnus albacares.*

The modal class interval was 31-41 cm: many small fish are caught by trolling liner and purse seiner.

The relationship between length and weight of T. albacares. The relationship between length and weight is presented on the graph, according to the characteristics of the fish growth pattern, as shown in Figure 3.

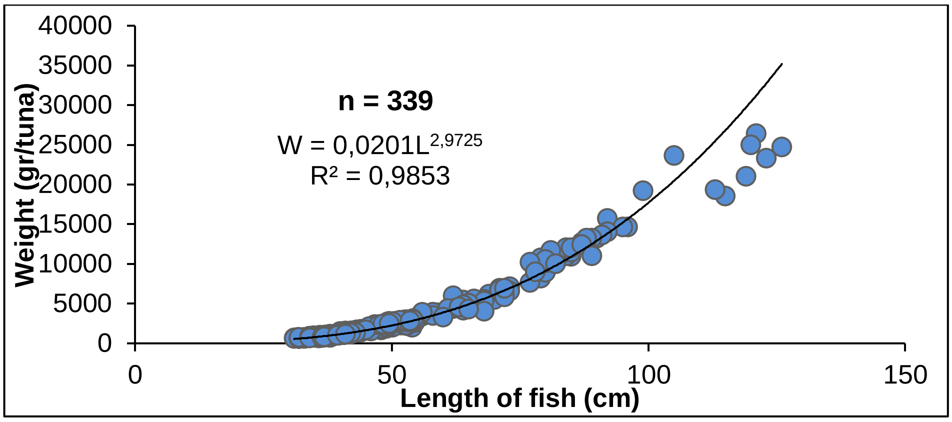

Figure 3. Length-weight relationship of *Thunnus albacares.*

From the results of the analysis of the length-weight relationship of the species *T. albacares*, the following equation was determined: $W=0.0201\ L^{2.9725}$, with a value of b=2.9725. Then a $t_{\text{-test}}$ was carried out on the value of b at a 95% confidence interval and obtained $t_{count}<t_{table}$ ($t_{count}=1.393$; $t_{table}=1.967$), therefore H_0 was accepted, which means that the increase rates in length and weight are not significantly different, so that it can be said that the increase in length is proportional to the increase in weight (isometric).

From the results of the t_{test}, it is necessary to carry out further calculations to obtain a new *T. albacares* length-weight relationship equation, by substituting the values of $\bar{Y}$ and $\bar{X}$ using $\bar{Y} = a' - 3\bar{X}$, namely $W=0.018055\ L^3$. Calculation of the growth pattern was carried out using the $t_{\ test}$ ($t_{count}=0.05$), at a 95% confidence interval ($\alpha=0.05$), producing a coefficient of determination (R^2) of 0.9928 and a correlation coefficient (r) close to 1. This shows that an increase in the length affects the weight gain, meaning that the correlation or relationship between length and fish weight is strong and positive.

Length at first capture (Lc). Calculation of the size of the first catch of *T. albacares* was carried out using data on the length and number of fish caught in purse seine catches. Based on the observation of the 70 caught specimens, the Lc was 39.55 cm as it can be seen in Figure 4.

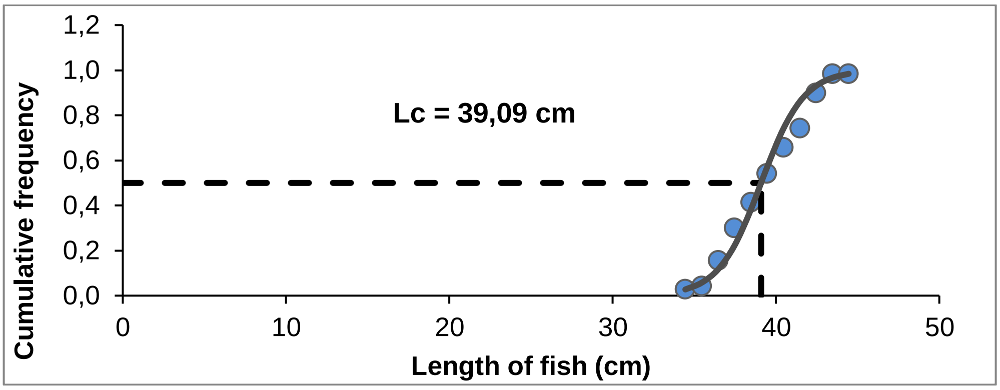

Figure 4. Length at first capture of *Thunnus albacares* on purse seine.

Fishing ground. The dominant fishing grounds for fishermen in the province of Maluku are located in the Banda Sea (FMA RI 714). These areas are usually approached by *T. albacares* due to environmental factors, food availability and they are also spawning and egg-laying areas. The highest catch occurs at the beginning of the East season, also called the harvest season, from October to December. The lean season is from May to July, the western season is from December to January and the transition season is from April to May. The catches obtained depend on the season, currents and wind, which might be obstacles for going to sea and succeeding to make catches.

Stock status in Fishery Management Area - Republic of Indonesia (FMA-RI 714)
CPUE and MSY T. albacares. In Table 2 it can be seen the production data and fishing effort of *T. albacares* in FMA RI-714 by hand liner, troll liner, purse seiner, and the pole and liner.

Table 2

FMA RI-714 production and fishing effort

Year	*Production (tons)*					*Trip*			
	Purse seiner	*Trolling liner*	*Hand liner*	*Pole and liner*	*Total*	*Purse seiner*	*Trolling liner*	*Hand liner*	*Pole and liner*
2008	3,868.71	3,813.07	39.29	3,127.51	10,848.57	23,419	427,899	201	8,546
2009	3,997.51	4,961.22	1,500.39	3,754.16	14,213,28	21,373	392,497	248,406	9,457
2010	3,982.52	1,335.69	993.14	2,752.55	9,063.90	43,622	474,562	311,339	8,429
2011	4,710.08	9,739.77	2,424.13	6,639.34	23,513.32	35,888	433,171	191,396	7,641
2012	5,169.07	14,869.32	1,017.65	4,037.61	25,093.65	42,027	432,897	226,447	10,617
2013	19,288.48	10,298.59	3,125.72	3,964.70	36,677.49	32,010	484,526	186,753	10,646
2014	6,094.66	3,863.20	4,381.17	4,397.88	18,736.91	39,017	141,506	293,614	7,797
2015	4,505.92	381.21	2,587.83	5,494.17	12,969.12	34,787	247,776	85,352	8,922
2016	10,159.34	879.72	3,675.05	7,856.27	22,570.37	41,596	291,150	204,868	8,657
2017	13,102.44	1,476.79	5,140.45	8,321.75	28,041.43	38,453	226,620	191,767	8,125
2018	13,661.33	2,145.53	6,076.82	12,722.25	34,605.93	48,078	255,188	157,874	8,698

There are differences in fishing productivity between hand liner, troll liner, purse seiner, and pole and liner, it is necessary to standardize productivity, to obtain the Fishing Power Index (FPI) as can be seen in the Table 3.

Table 3

Productivity and fishing power index (FPI) in *Thunnus albacares*

Year	*Productivity (tons trip^{-1})*			
	Purse seine	*Trolling line*	*Hand line*	*Pole and line*
2008	0.1652	0.0089	0.1955	0.3660
2009	0.1870	0.0126	0.0060	0.3970
2010	0.0913	0.0028	0.0032	0.3265
2011	0.1312	0.0225	0.0127	0.8689
2012	0.1230	0.0343	0.0045	0.3803
2013	0.6026	0.0213	0.0167	0.3724
2014	0.1562	0.0273	0.0149	0.5641
2015	0.1295	0.0015	0.0303	0.6158
2016	0.2442	0.0030	0.0179	0.9075
2017	0.3407	0.0065	0.0268	1.0242
2018	0.2841	0.0084	0.0385	1.4627
Average	0.2232	0.0136	0.0334	0.6623
CPUE	0.2232	0.0136	0.0334	0.6623
FPI	0.3370	0.0204	0.0504	1

Based on Table 3, the huhate is used as standard fishing gear, because its productivity is larger than other fishing gear. Furthermore, the standardization process, resulting from the multiplication of the FPI with the number of fishing gears, produces the standard effort values presented in Table 4.

Table 4

Standardization of *Thunnus albacares* catching efforts

Year	*Purse seiner*	*Trolling liner*	*Hand liner*	*Pole and liner*	*Total effort standard*	*CPUE (ton trip^{-1})*
2008	7,892	8,765	10	8,546	25,213	0.4303
2009	7,203	8,040	12,515	9,457	37,215	0.3819

Year	Purse seiner	Trolling liner	Hand liner	Pole and liner	Total effort standard	CPUE (ton $trip^{-1}$)
2010	14,701	9,721	15,686	8,429	48,538	0.1867
2011	12,094	8,873	9,643	7,641	38,251	0.6147
2012	14,163	8,868	11,409	10,617	45,057	0.5569
2013	10,787	9,925	9,409	10,646	40,768	0.8997
2014	13,149	2,899	14,793	7,797	38,637	0.4849
2015	11,723	5,076	4,300	8,922	30,022	0.4320
2016	14,018	5,964	10,322	8,657	38,961	0.5793
2017	12,959	4,642	9,662	8,125	35,388	0.7924
2018	16,202	5,227	7,954	8,698	38,082	0.9087

The effort and yield data shown in Table 3 will produce CPUE fluctuations every year as shown in Figure 5.

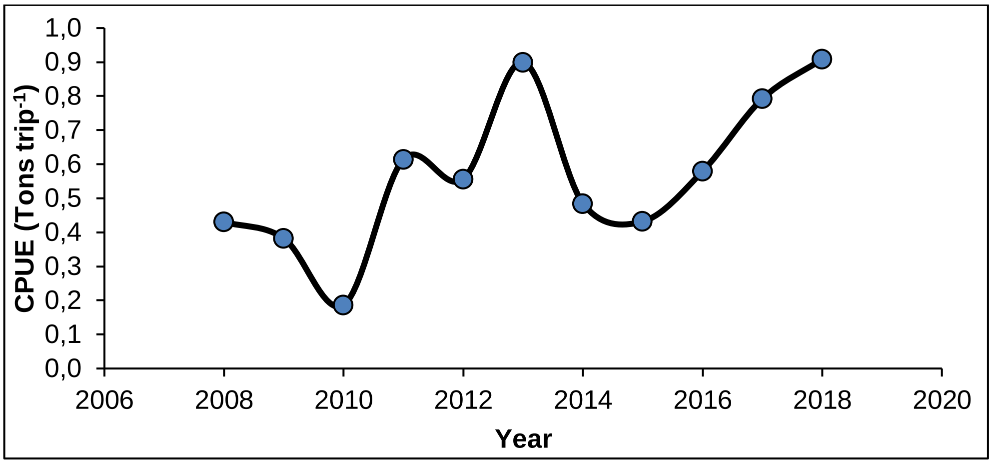

Figure 5. *Thunnus albacares* CPUE fluctuation in FMA-RI 714.

From Figure 5 it can be concluded that 2013 was the highest CPUE point. Even though the CPUE decreased from 2014 to 2015, the conditions did not disturb the sustainability of tuna fishing activities in FMA-RI 714.

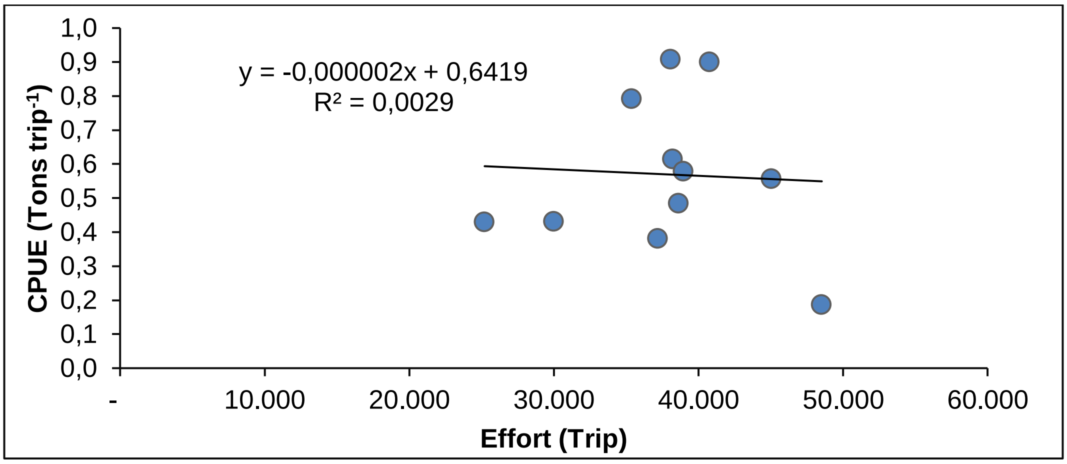

Figure 6. Linear equations of CPUE and effort *Thunnus albacares.*

The relationship between CPUE and effort in Figure 6 shows that the value of the estimation parameter for tuna fish is obtained by an intercept (a) = 0.6419 and a slope (b) = -0.000002 so as to form the Schaefer linear equation CPUE = -0.000002x + 0.6419. This relationship can be interpreted that by catching x units per year, it will reduce the CPUE value by 0.000002 tons per year. The conditions described in the linear equation produce a value of R^2 = 0.0029 which means that around 0.29% the CPUE is influenced

by the effort. Thus, the R^2 value indicate that the influence of the variables used in this model is not strong.

Maximum Sustainable Yield (MSY) and Economic Maximum Sustainable Yield (EMSY) calculation data for *T. albacares* in FMA-RI 714 using the Schaefer Linear method are presented in Table 5. The results of biological analysis using the Schaefer Linear model approach can produce an MSY value of 54,027 tons with a standard effort/EMSY of 168,332 trips.

Table 5

MSY and EMSY *Thunnus albacares* Based on Schaefer linear model calculations

Year	*Number of catches (Tons)*	*Total standard effort*	*CPUE (Schaefer)*
I	*Yi*	*X*	*Y*
2008	10,848.5	25,213	0.4303
2009	14,213.2	37,215	0.3819
2010	9,063.9	48,538	0.1867
2011	23,513.3	38,251	0.6147
2012	25,093.6	45,057	0.5569
2013	36,677.5	40,768	0.8997
2014	18,736.9	38,637	0.4849
2015	12,969.1	30,022	0.4320
2016	22,570.3	38,961	0.5793
2017	28,041.4	35,388	0.7924
2018	34,605.9	38,082	0.9087
Total	236,333.9	416,131	6.2676
Average	21,484.9	37,830	0.5697
Intercept a			0.6419
Slope b			-0.000002
MSY Schaefer: -a^2/4b			54,027
EMSY Schaefer: -a/2b			168,332
Total Allowable Catch (TAC) 80% MSY			43,221.80

Based on linear model calculations, biological saturation yields have not occurred in *T. albacares* from FMA RI-714, which is indicated by actual catches that are not close to their sustainable potential (MSY). This is evidenced by the actual catch in 2018 which reached 34,605.9 tonnes, not yet exceeding the potential TAC of 80% of the MSY value (43,221.80 tonnes). The sustainable potential curve (MSY) of *T. albacares* can be seen in Figure 7.

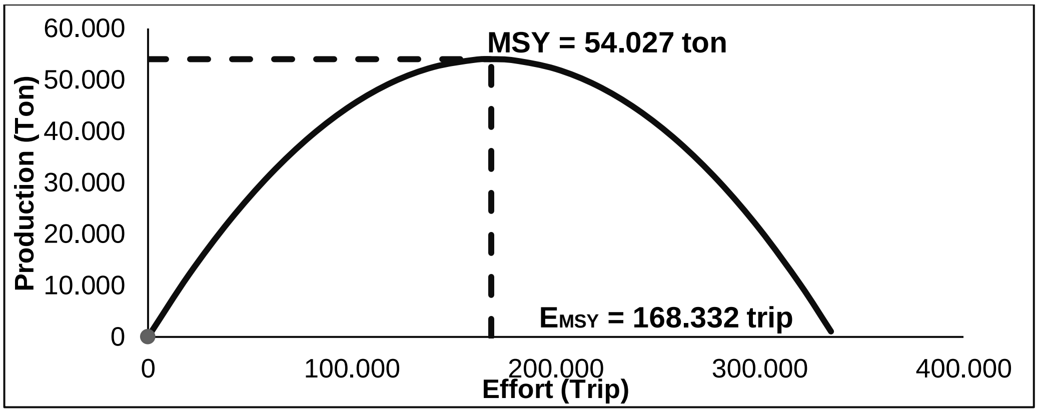

Figure 7. Stock equilibrium curve (MSY) of *Thunnus albacares* in FMA RI-714.

Conclusions. The biological aspects of *T. albacares* in Maluku waters show that the growth pattern of tuna is isometric. The exploitation of *T. albacares* is in a condition where

production continues to increase with a low level of fishing gear selectivity, therefore regulating and supervising the fishing gear are required.

Conflict of interest. The author declares no conflict of interest.

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Authors:
Ratna Suharti, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: r_suharti@yahoo.com
Mira Maulita, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: maulita.stp@gmail.com
Firman Setiawan, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: firmansetiawan001@gmail.com
Dadan Zulkifli, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: belfyludaputri@gmail.com
Basuki Rachmad, Faculty of Aquatic Resources Management, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: basukibye248@gmail.com
Maman Hermawan, Faculty of Fishing Technology, Jakarta Technical University of Fisheries, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: mhermawan60@gmail.com
Mantani Sayuri, Department of Ships Navigation, Japan Agency of Maritime Education and Training for Seafarers, Marine Technical College, Ashiya City 659-0026, Hyogo, Japan, e-mail: mantani-s6ea@jmets.ac.jp
Erick Nugraha, Jakarta Technical University of Fisheries, Faculty of Fishing Technology, Pasarminggu 12520, South Jakarta, Indonesia, e-mail: nugraha_eriq1@yahoo.co.id

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Eni Kovacs <ek.bioflux@gmail.com>
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