Model and nature of growth of red snapper fish (*Lutjanus argentimaculatus* (Forsskål, 1775)) fishing catch of bottom fish pots in Bunyu waters, North Kalimantan

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Abstract. This study aims to inform about the trends of biological conditions (models and nature of growth) as actual data in the sustainable management of red snapper (*Lutjanus argentimaculatus*) resources in Bunyu waters. Model of growth used the von Bertalanffy's approach (infinitive length estimation, growth coefficient, and estimated age at null theoretical length parameters) and the nature of growth with the length-weight relationship (LWR) and condition factors approach. Total samples of red snapper were 42 (20 males and 22 females). Red snapper is estimated to reach an infinitive length of 53.86 cm with a growth coefficient of 0.1043 cm year^{-1} and a t_0 value (the estimated age of the fish) of -0.9350. The results of LWR analysis on the total length (TL) against the weight (W) resulted in W value of 2.502 (negative allometric), on the standard length (SL) with weight (W) resulting in b value of 2.238 (negative allometric), and at the fork length (FL) with the weight (W) produces a b value of 2.471 (negative allometric). The proportion of body shape of red snapper fish samples based on Kn values generally has a more flat/thin body. The percentage value of the condition factor which shows the proportion of flat/thin body shape in the TL-W relationship was 50.0%, 52.4% for SL-W, and 57.1% for FL-W). Sample fish with a fat proportion is 42.9% (TL-W), 45.3% (SL-W), and 40.5% (PL-W).
Key Words: von Bertalanffy growth, the length-weight relationship, condition factors, red snapper (*Lutjanus argentimaculatus*), bottom fish pots.

Introduction. Bunyu Island is a sub-district in Bulungan, North Kalimantan Province. Bunyu Island has an area of 198.32 km^2 which is characterized by a small island surrounded by the ocean with fishing potential. Most of the residents of Bunyu Island work as fishermen, mainly using bottom fish pots, as well as oil and gas workers. The number of residents who work as fishermen is 122 with various fishing gear such as bottom otter trawls, hand lines, longlines, gillnets, and bottom fish pots (Anonymous 2019).

Red snapper (*Lutjanus argentimaculatus*) is a fish that can be caught in the operation of a bottom fish pots in Bunyu waters (Figure 1). Red snapper is included in the Lutjanidae family (Allen 1985). Red snapper is widespread in Indonesia, including in Bunyu Island waters with a solid substrate, mangrove forests or seaweed-rich waters (Melianawati & Andamari 2009; Rikza et al 2013; Wahyuningsih et al 2013; Prihatiningsih et al 2017).

Red snapper in Bunyu Island was caught using bottom fish pots. The use of bottom fish pots in Bunyu is appropriate due to the basic conditions of Bunyu waters and to the vicinity of the northeastern Tarakan waters which have rocky and sandy substrata. Bottom fish pot fishing gear used by fishermen in Bunyu waters is indicated to be environmentally friendly. For that, the material used in the construction of the bottom fish pots is woven bamboo (Firdaus et al 2019). According to Sudirman & Mallawa

(2004), the bottom fish trap is a fishing gear installed in the water to make it easier for fish or catches target to enter the trap and make it difficult to get out. According to Ambarsari (2014) in Firdaus et al (2019), basic bottom fish pots fishing gear is generally made from natural materials, such as bamboo, wood, or other materials such as nets and included in the type of traps added with the bait as a factor supporting the success of the fishing operation.

Figure 1. Bottom fish pots in Bunyu Water, Indonesia.

The catch of bottom fish pots in Bunyu waters is demersal fish that have important economic value, such as red snappers, dogtooth tunas, groupers, and golden snapper. Specifically the red snapper is one of the most dominant fish catches of bottom fish pots in Bunyu waters. During the operation of bottom fish pots, it catches demersal fishes with a variety of species and sizes, in terms of both length and weight. Length and weight are two basic components in species biology at the individual and population levels (Naeem et al 2012). In this case, length-weight relationship (LWR) is one of the important factors in the fisheries industry used for predicting the best length and the most suitable time to collect certain fish species (Abobi & Ekau 2013).

Growth parameters (models and growth patterns) of red snapper, especially in the genus of *Lutjanus*, have been widely studied in Indonesian waters (Melianawati & Andamari 2009; Sumiono et al 2010; Rikza et al 2013; Wahyuningsih et al 2013; Nurulludin et al 2016; Prihatiningsih et al 2017). Red snapper in the waters of Barru waters, South Sulawesi shows that the pattern of growth is positive allometric with W value of 3.13 (Sumiono et al 2010). Red snapper in South Kalimantan waters shows the growth parameter value ($L\infty$) of 57.86 cm; K of 0.238 cm year^{-1}; and t_0 of 0.588 years (Prihatiningsih & Wahyuningsih 2012). The results of research by Wahyuningsih et al (2013) with samples from eastern Java waters showed the growth parameter value ($L\infty$) of 97.65 cm; K of 0.220 cm year^{-1}; and t_0 of –0.024 years. Snapper growth parameters are also described by Prihatiningsih et al (2017) with samples from the southern waters of Banten, show that the pattern/nature of the growth is isometric with W values of 3.030 (male) and W of 3.033 (female).

The values in the growth parameters are biological variables that are very important to be considered in the pattern of utilization of a fishery resource. Fisheries management needs to pay attention to biological values in the utilization pattern of these resources, including red snapper found in Bunyu waters. Analysis of growth patterns is useful in determining selectivity in fisheries management (Mulfizar et al 2012). Growth parameters such as K (growth coefficient), $L\infty$ (estimated maximum length), and t_0 (estimated fish age) are used to assess the relationship between length and age (Kronbak et al 2009). Growth analysis is the most often studied parameter in fish populations as an important consideration in the productivity of fish resource stocks (Jennings et al 2001). Research on biological aspects using the growth pattern and age structure approach of red snapper caught in Bunyu waters aims to look at trends in these biological aspects and provide actual data as important values in the sustainable management of red snapper resources.

Material and Method. Research on growth models uses the von Bertalanffy growth pattern approach and age structure of red snapper in Bunyu waters. The nature of growth is estimated by using the LWR and condition factors approach.

Site location. The research location with 6 spots was established in the South and Southeast of Bunyu Island, which is a fishing ground for red snapper (Figure 2).

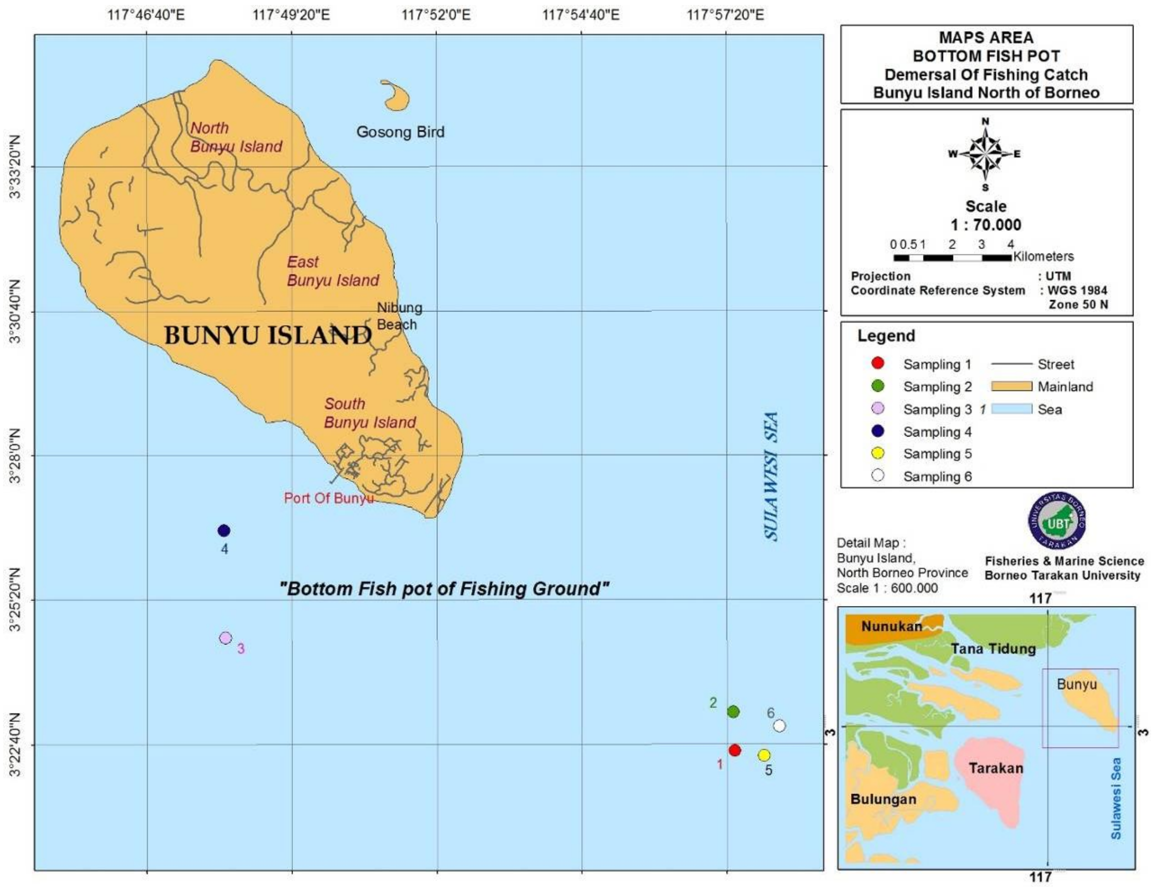

Figure 2. Sampling location *L. argentimaculatus* by bottom fish pots at Bunyu waters.

Sampling and data collection. The study was conducted in 14 sampling periods during 4 months (April-July 2019). Demersal fishing for red snapper operating the bottom fish pot traps in Bunyu waters was carried out at 08.00-15.00, 2 days per week for 2 weeks in each month. In May, there was only one sampling period, so for 4 months, there were 14 sampling periods.

Every month, ±12 red snapper fish were collected. Observation and measurement of fish samples include the data collection of total length (TL), standard length (SL), fork length (FL), and total weight (TW). The measurement use a measuring instrument in a unit of centimeter (length) and grams (weight).

Data analysis. Analysis of fish growth uses the von Bertalanffy model with the Gulland (1983) and Sparre & Venema (1999) approach. The fish growth parameters that were examined include L_∞ (infinitive length), K (growth coefficient) and t_0 (estimated fish age), using a growth model developed by von Bertalanffy, namely: $Lt = L_\infty [1 - e^{-k(t-to)}]$. To estimate the K and L_∞ parameters, Gulland (1983) and Sparre & Venema (1999) approaches were used as follows: $\Delta L/\Delta t = a - b (L_t + L_{t+1})/2$, with $\Delta L/\Delta t$ = length increase per age difference; $(L_t + L_{t+1})/2$ = average length between two different ages; and a, b = constants.

So the length value of the K and the L_∞ from the above equation are estimated as follows: $L_\infty = - a/b$, and $K = - b$. The estimated value of t_0 was done by using Pauly (1984) empirical formula, namely: $\ln(-t_0) = - 0.3922 - 0.2752 \ln L_\infty - 1.038 \ln K$. L_∞ and K values were obtained using fish frequency distribution data with the help of Ms.

Excel 2013 program. Age structure analysis using the mode class shift method with the von Bertalanffy model (Sparre & Venema 1999), namely: $L_t = a + b * \Delta L/\Delta t$.

For the body shape analysis of red snapper we used the relationship of length (L) and weight (W) of fish in the form of cubic patterns and the relationship of bust (L_b) with L of fish is a simple linear form (Effendie 2002; Merta & Badruddin 1992), with a simple regression equation of $Y = a + X^b$, becomes $W = a L^b$ and logoed becomes $\ln W = \ln a + b \ln L$. The W value of the LWR in the nature of fish growth expresses the shape of the fish's body. The fish's body expression can be shaped into three categories: thin/slender, ideal/proportional, or fat/plump. A W value of 3 means that there is isometric growth (balanced growth). If the value of W is > 3 or < 3 this means allometric growth (unbalanced growth). This unbalanced growth trait can be a negative allometric value (W < 3) which means lean/thin body shape and positive allometric value (W > 3) which means plump/fat fish body shape (Effendie 2002).

To find out the value of W is different or equal to 3, we performed the F test (data distribution) and continued with the t-test (equal test), to describe the condition factor whether the value of W = 3 or b ≠ 3 (Effendie 2002) with the hypothesis received H_O then b = 3 (growth is isometric, where length growth is always followed by weight gain), or accept H_I then b ≠ 3 (growth is allometric, where length growth is not always followed by weight gain), with the condition:

$t_{count} < t_{((a/2\ ;\ (n-2))}$, accept H_O, decline H_I

$t_{count} > t_{((a/2\ ;\ (n-2))}$, accept H_I, decline H_O

The shape of fish used to illustrate isometric growth parameter is expressed by using Lagler's condition factor value approach (Effendie 2002) (K value in the metric system is calculated by using a value of 10^5 where the result of K value is below 1), namely:

$$K(TI) = 10^5 \times \frac{W}{L^3}$$

Le Cren's condition factor values (Raeisi et al 2011) for allometric growth traits are:

$$Kn = \frac{W}{\hat{W}}$$

W is the actual fish weight (gram) and the estimated fish weight (gram) from the log W = a + b * Log L. The value of the modified condition factor of Fulton's (Abobi & Ekau 2013), namely:

$$K = 100 \times \frac{W}{L^b}$$

W values (grams) and L (cm) are absolute size values for fish samples.

Results. A total of 42 red snapper fish samples were collected, with 22 females (52.4%) and 20 males (47.6%). Measurement results for TL, SL, FL, and TW are shown in Table 1.

Table 1

Variation in the body size of *Lutjanus argentimaculatus*

L. argentimaculatus		*Size variable*			
		Total length (cm)	*Standard length (cm)*	*Fork length (cm)*	*Weight (g)*
Male	Max.	56.0	46.5	49.8	2392.0
	Min.	27.0	19.5	23.0	340.5
	Mean	40.3	32.5	35.7	1084.7
Female	Max.	55.0	46.0	49.0	3121.1
	Min.	29.0	21.7	26.0	416.8
	Mean	39.2	32.0	35.2	1107.9

The equation for growth model of red snapper. Based on the results of growth analysis using the von Bertalanffy method with Gulland (1983), Sparre & Venema (1999), and Pauly (1984) approach, the equation for the growth model of red snapper is:

$$Lt = 53.861 \{1 - 2.71828^{-0.1043 (t - 0.9350)}\}.$$

Explanation of the equation generated from the growth analysis using the von Bertalanffy method for red snapper samples is that the sample has an L_∞ value of 53.86 cm and a K value of 0.1043 cm year^{-1} and t_o (fish age) value of –0.9350 (Table 2 and Figure 3).

Table 2

Growth parameters of *L. argentimaculatus*

Symbol	*Value*	*Units*	*Description*
K	0.1043	cm year^{-1}	Growth coefficient
$L\infty$	53.861	cm	Infinitive length
t_o	-0.9350	year	Conjecture of theoretical age at zero length

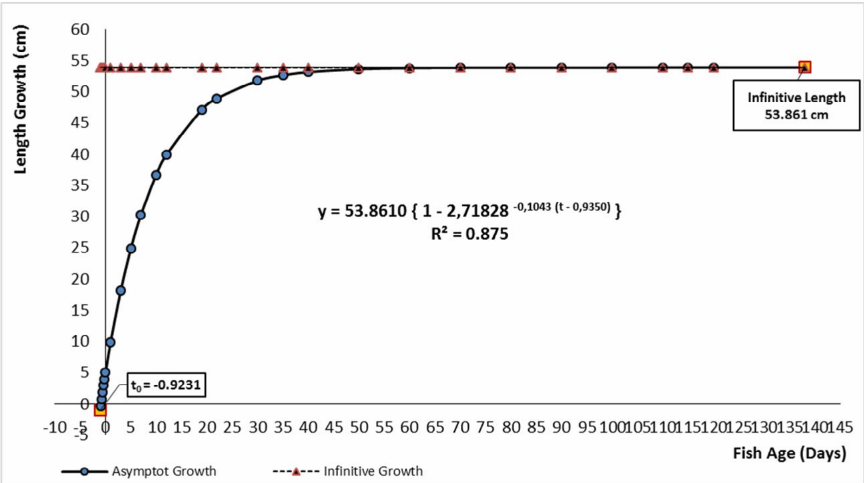

Figure 3. Growth curve of von Bertanlanffy model of *L. argentimaculatus*.

Correlation between length and weight of red snapper. The correlation of L and W in red snapper samples during the study was analyzed using logarithmic linear regression and parabolic exponential regression approaches. Logarithmic linear regression analysis of TL with W produces logarithmic linear equations (Figure 4) of Log W = 2.5017 Log L - 0.9987 (R^2 = 0.9036).

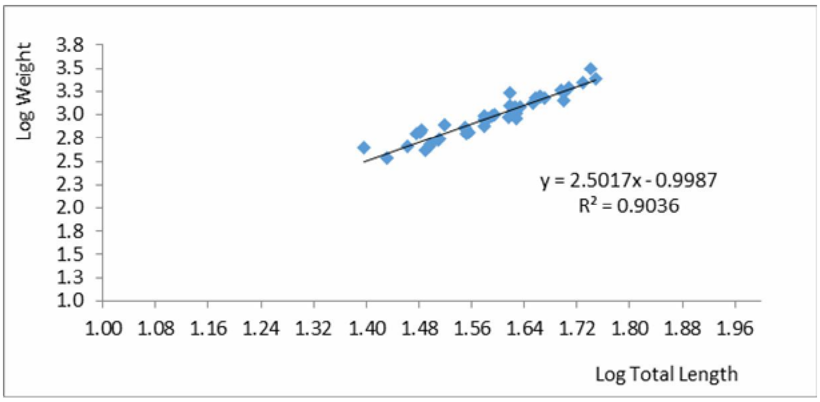

Figure 4. Logarithmic total length and weight relationship of *L. argentimaculatus*.

Correlation of logarithmic linear regression of SL with W produces an equation (Figure 5) of Log W = 2.2377 Log L – 0.3725 (R^2 = 0.8622).

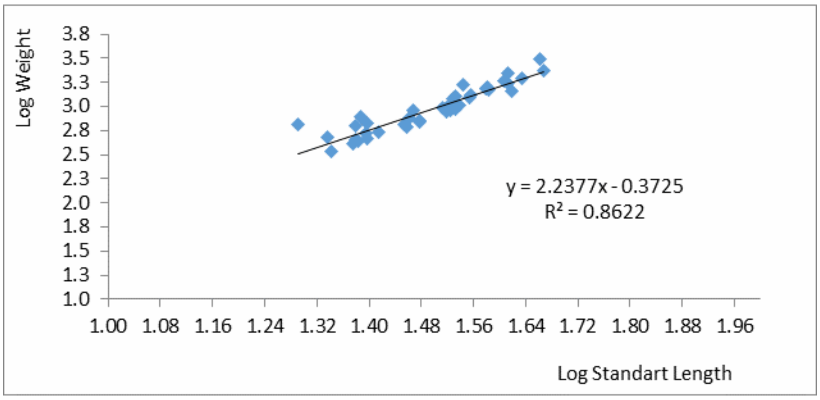

Figure 5. Logarithmic standard length and weight relationship of *L. argentimaculatus*.

Logarithmic linear regression analysis of the correlation between FL and W produces an equation (Figure 6) of Log W = 2.4708 Log L – 0.8257 (R^2 = 0.9018).

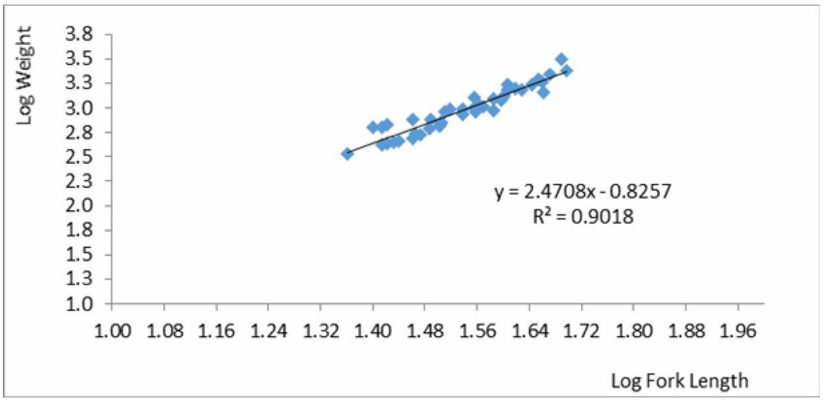

Figure 6. Logarithmic fork length and weight relationship of *L. argentimaculatus*.

Furthermore, in the parabolic exponential regression analysis, the correlation between the TL and W results in the equation (Figure 7) of W = 0.100*$L^{2.5017}$ (R^2 = 0.9036).

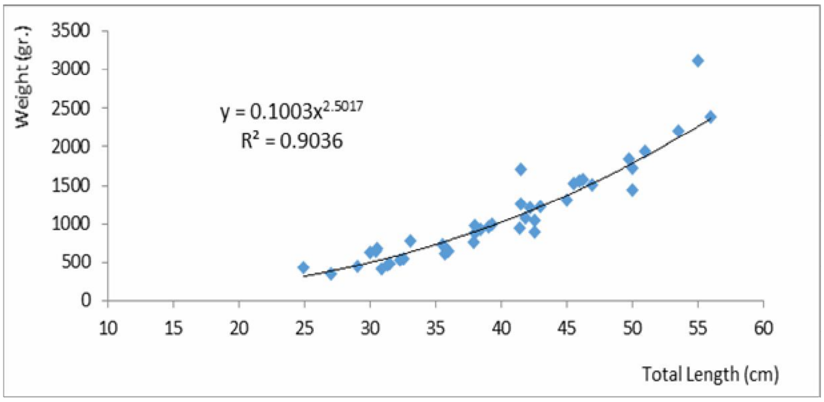

Figure 7. Parabolic total length and weight relationship of *L. argentimaculatus*.

In the exponential regression, the SL with W produces the equation (Figure 8) of W = 0.4241*$L^{2.2377}$ (R^2 = 0.8622).

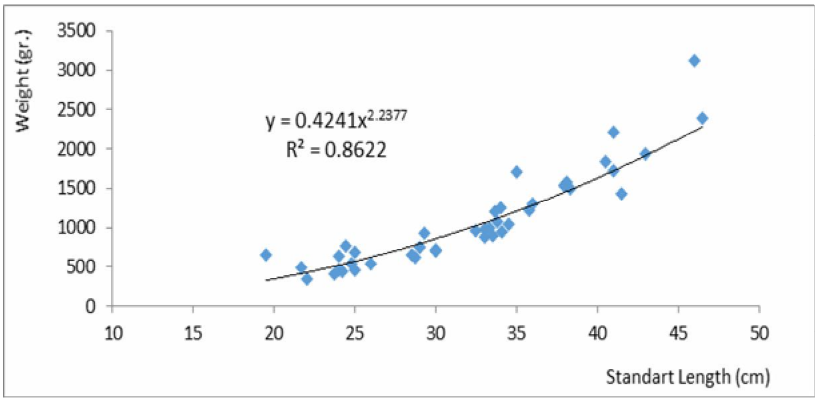

Figure 8. Parabolic standart length and weight relationship of *L. argentimaculatus*.

Parabolic regression analysis between FL and W yields an equation (Figure 9) of W = $0.1494*L^{2.4708}$ (R^2 = 0.9018).

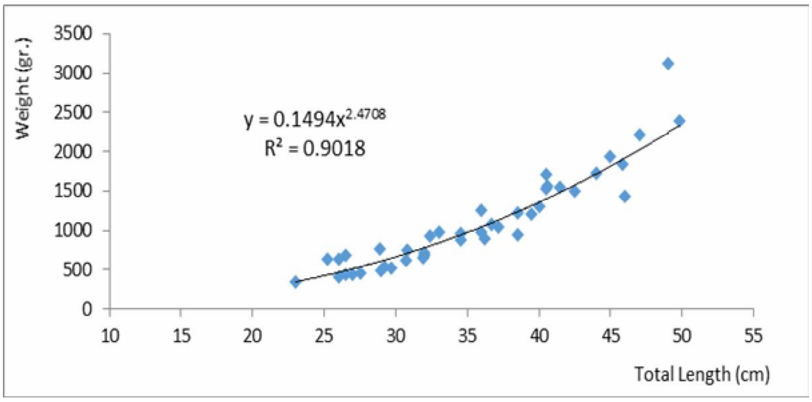

Figure 9. Parabolic fork length and weight relationship of *L. argentimaculatus*.

The LWR analysis of the TL, SL, and FL to the W using the logarithmic regression (Figures 4-6) and the exponential regression (Figures 7-9) approach produces a coefficient of b (slope) around 2.237-2.502. The value of b (slope) is smaller than 3 (b < 3), which shows the growth pattern of the sample fish is negative allometric.

To ensure the value of the slope coefficient (b) from the analysis of the LWR is not 3 (b ≠ 3), it is necessary to test the data with the F test and t-test. Based on the F test results, it is known that the value of $f_{count} < f_{table}$, and based on the statistical rule the data distribution is not identical. Continued in the t-test, resulted in a correlation value of 0.952; the significance value is 1.202E-40; and $t_{table} < t_{count}$. The rule of the decision is to accept H1 with the explanation that the value of the slope coefficient (b) is not 3 (b ≠ 3) (Table 3).

Table 3

T-test result of length-weight relationship of *L. argentimaculatus*

t-Test: paired two sample for means					
Pearson correlation	*Significance*	*t-count*	*t-table*	*Rule*	*Explanation*
0.9519 (> 0.5 / 95.19%)	1.202E-40 (p < 0.01)	59.443	2.021	$T_{count} > t_{table}$ accepted H_1	have correlation L and W (allometric, b ≠ 3)

Red snapper body condition. The condition factor analysis of the red snapper samples was carried out with the Le Cren's condition factor values (Kn) approach on the nature growth of negative allometric. The results showed that the Kn values in red snapper samples range from 0.745 to 1.338 with an average of 1.008. The proportion of body shape of red snapper generally has a flat/thin body with a percentage of 50.0% (TL-W relationship); 52.4% (SL-W relationship); and 57.1% (FL-W relationship) (Table 4). The results of the condition factor analysis also showed that based on length (TL, SL, and FL) and total weight (TW) data, fish samples with plump/fat body were 40.5% (TL-TW); 42.9% (SL-TW); and 40.5% (FL-TW) (Table 4).

Table 4

Category of fish body shape based on the value of Le cran's factor condition of *L. argentimaculatus*

Criteria / Category	*Range*	*Total length-weight*		*Standart length-weight*		*Fork length-weight*	
Very flat / thin	≤ 0.50	0	0.0%	0	0.0%	0	0.0%
Flat / thin	0.51-0.99	21	50.0%	22	52.4%	24	57.1%
Propotional	1	3	7.1%	1	2.4%	1	2.4%
Rounded / fat	1.01-1.49	17	40.5%	18	42.9%	17	40.5%
Very rounded / fat	≥ 1.50	1	2.4%	1	2.4%	0	0.0%
Total		42	100.00%	42	100.00%	42	100.00%

Discussion. The red snapper is the main target species to be caught by bottom fish pot traps in Bunyu waters. This fish is categorized as high value demersal fisheries resource. During sampling period, average weight of male and female was up to 1.084 kg and 1.107 kg respectively with price reaching about IDR 60,000 per kg. In Indonesia, besides groupers, the red snapper has high economic value and demand as export commodities of fisheries sub-sector. This fish is also widely distributed in Indonesia, including in Sumatra, Java, Nusa Tenggara, Borneo, Celebes, Moluccas, and Papua waters (Melianawati & Andamari 2009; Wahyuningsih et al 2013; Rikza et al 2013). The fish live in hard-bottomed waters, mangrove or associated with seaweed ecosystem (Anonymous 1987, 1992).

It was found that average TL of male and female red snapper samples was 40.3 cm and 39.2 cm respectively. While average SL of male and female was 32.5 cm and 32.0 cm respectively. In addition, average FL of male and female was 35.7 cm and 35.2 cm respectively. The average TL of red snapper in this study was greater than that of all previous research done by Holloway et al (2015) (23.5 cm) and Prihatiningsih et al (2017) (22.5 cm). Differences in size are possible due to differences in fishing gear and catchment area. The size of the red snapper caught in Bunyu waters is largely determined by the size of entrance hole of the bottom fish pots used. Nikolsky (1963) stated that differences in fish size are also influenced by environmental conditions such as abundance, availability of food, temperature, and light in different waters. Observation on red snapper samples in Bunyu waters has strongly indicated that the fish caught has already matured. This is in accordance with research done in Sape Strait (East Nusa Tenggara) and Kupang waters which showed that the red snapper with a TL of 38 cm and 34.5 cm, respectively, have matured gonad characteristics (Sumiono et al 2010). Karyaningsih & Suhendrata (1992) added that the species in Lutjanidae family in Java Sea reached their length at first maturity (L_m) at TL of 55 cm. Therefore further research about red snapper biology in Bunyu waters need to be conducted in order to get more comprehensive length data comparing to data from other waters.

Growth parameter at L_∞ or the estimated maximum length that can be achieved by red snapper in Bunyu waters was generally smaller in size compared to other previous research. Red snapper in the eastern Java Sea and in northern Java waters had an L_∞value of 97.65 cm (Wahyuningsih et al 2013) and 64.4 cm (Herianti & Djamal 1993) respectively. Anderson (1987) also reported that deep-sea snapper samples (*Etelis radiosus*) have a bigger L_∞ value. Prihatiningsih & Wahyuningsih (2012) informed the little bit bigger size of L_∞ of red snapper in South Kalimantan waters (57.86 cm).

Other growth parameters such as K and the estimated age at zero length (t_0) also showed differences in values with other studies. In general, K value of red snapper samples in Bunyu waters (0.1043 cm year^{-1}) was smaller than the results of other studies. Wahyuningsih et al (2013) stated that red snapper in the East Java Sea had a K value of 0.220 cm year^{-1}. While K value of red snapper samples in the north Java waters was 0.338 cm year^{-1} (Heriati & Djamal 1993) and in South Borneo waters was 0.238 cm year^{-1} (Prihatiningsih & Wahyuningsih 2012). The small K value of the red snapper sample in Bunyu waters indicates that the growth rate (length and weight) is quite slow, which is assumed to be 0.1043 cm year^{-1}. According to Gulland (1983), if K value is less than one it indicates that the fish has slow growth. Slow growth of red snapper in Bunyu waters affects the pattern of stock utilization which is easy to get overfishing. In other words, red snapper in Bunyu waters has the opportunity to be caught at a small size or not yet reach a catchable size due to slow growth rate. Wahyuningsih et al (2013) explained that the growth rate affects the utilization pattern. To preserve fish resources, young fish must be allowed to grow before being caught.

The small value of the K is thought to be influenced by food and aquatic environment factors. There were other factors that were also able to influence the K, namely sampling strategies (method and number of samples). In this study, the samples were collected using bottom fish pots with specific entrance diameter sizes (40 cm outside and 20 cm inside). This specific fishing gear design probably led to get bigger size of the red snapper samples during study. Aziz et al (1992) as cited by Prihatiningsih et al (2013) stated that differences in growth parameters can be influenced by differences in soaking time, season, fish size, fishing gear used, and the area of capture at the sampling time. Widodo (1988) added that the difference in the value of growth parameters is influenced by the composition of the sample and the method used. The growth coefficient value is high if young fish (small-size) are caught more and vice versa if adult fish (large-size) are caught a lot, then the growth coefficient value is low (Prihatiningsih et al 2013).

LWR analysis illustrated that all values of b (slope), SL (2.2377), FL (2.4708), and TL (2.5017) were smaller than 3 (b < 3). Based on the F test results, it is known that the f_{count} value is 0.146 and the f_{table} value is 0.591, so the $f_{count} < f_{table}$, which means the data distribution is not identical and can be continued with t-test. Statistical results on the t-test produce a correlation value of > 0.5; the significance value is less than 0.01 ($p < 0.01$), and the t_{table} is smaller than the t_{count}. Thus, the value of the slope coefficient (b) does not equal 3 ($b \neq 3$). This condition indicated that the growth of the red snapper in Bunyu waters was negative allometric. It meant that increase in weight is slower than that in length. The negative allometric growth also shows that the fish has a flat or thin body. Different result of LWR was reported by Sumiono et al (2010). They found that red snapper in Barru waters, South Celebes has b value of 3.1268 (positive allometric). While study done by Prihatiningsih et al (2017) also informed that red snapper in the southern waters of Banten has isometric growth pattern both on male (3.030) and female (3.033). In general this relationship analysis can be used to estimate fish body shape and predict weight of fish at a certain length and vice versa (Badrudin & Wudianto (2004). Several researchers illustrated about the importance of LWR. Ridho & Patriono (2016) stated that fish growth patterns can be known by analyzing the LWR of fish, this relationship being able to explain the fish growth and environmental changes. Richter (2007) and Blackwell et al (2000) added that the measurement of fish's length and weight aims to find out the specific variations of fish’s weight and length individually or in groups and physiological conditions including their gonad development.

Kn analysis informed that red snapper in Bunyu waters had a range value of Kn = 0.745-1.338 with an average of 1.008. It meant that the body shape or body condition of the fish is flat (Effendie, 2002). Under natural conditions, fish that have flattened body shapes tend to have smaller Kn values (Melianawati & Andamari 2009). Effendie (2002) suggested that variations in the condition factor values depend on food, age, sex, and level of gonads maturity. The red snapper in Bunyu waters have condition factor value that lead to thin/flat body shape. Visually the sample is still in good condition. Effendie (2002) added that the fish is still in a good condition threshold with a Kn value of 1-3. Different result about condition factor was reported by Prihatiningsih et al (2017). They found that red snapper samples in the southern waters of Banten had Kn values ranging from 1.73 to 2.56.

The proportion of body shape of the red snapper in Bunyu waters based on the Kn values refers to the concept introduced by Effendie (2002) which has been modified with five body shape categories. Based on the regression approach of LWR on the data of TL and W, SL and W, as well as FL and W, the body shape of red snapper in Bunyu waters in general was flat/thin. The proportion value of the condition factor which shows the proportion of flat/thin body in the TL-W relationship was 50.0%; 52.4% (SL-W); and 57.1% (FL-W). Based on length (TL, SL, and FL) and weight (W) data, the body condition of the sample fish with a plump/fat proportion were 42.9% (TL-WT); 45.3% (SL-WT); and 40.5% (FL-WT).

Conclusions. Red snapper (*L. argentimaculatus*) in Bunyu waters was 52.4% male and 47.6% female. Its growth model obtained was $L_t = 53.861\ \{1 - 2.71828^{-0.1043\ (t - 0.9350)}\}$. Growth characteristics of the fish based on the length-weight relationship analysis against the total length, standard length and fork length to weight was negative allometric. The fish generally has a flat/thin body.

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