Current status of fringscale sardine fisheries (Sardinella fimbriata Valenciennes, 1847) (Clupeiformes: Clupeidae) at Makassar Strait, Indonesia

by Juliani Juliani

Current status of fringscale sardine fisheries (*Sardinella fimbriata* Valenciennes, 1847) (Clupeiformes: Clupeidae) at Makassar Strait, Indonesia

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Abstracts. It is known that the utilization of fringscale sardine (*S. fimbriata*) resource along Makassar Strait is considered intensive. Therefore, the sustainability of the fringscale sardine's resources is threatened. With regard to this matter, it is necessary to take a rational consideration on the utilization and management of the resources. It is hoped that information on fringscale sardine's (*S. fimbriata*) population dynamic will be used as the fundamental consideration in fringscale sardine resources management in attempt to support its sustainability. This study aims to measure the growth rate, mortality rate and recruitment pattern of Fringscale sardine (*S. fimbriata*). The results of the analysis show that the length of the first capture ($L_{50\%}$) was 133.79mm, it was longer than half of the asymptotic length (L_∞ = 164.85mm). It was also found that the relationship between *S. fimbriata* fishes was $W= 0.0037L^{1.819}$. The estimated growth with the reference of the Von Bertalanffy equation was $Lt= 164.85(1-e^{(-0,54(t-0.72))})$. The total mortality (Z) was 2.94 years^{-1}, natural mortality (M) was 1.45 years^{-1}, the captured mortality (F) was 1.49 years^{-1} and the exploitation rate (E) was 0.51 years^{-1}. These results showed that fishing conditions are close to optimum. The highest additional growth rate was in March at 19.84%.

Keywords : Status, Utilization, Resource, Fringscale sardine (*Sardinella fimbriata*).

Introduction. The Small-Scale Fisheries management (SSF) has become a concern in the past years (Evans and Andrews 2011; Hauzer et al 2013), even though Isaacs (2013) and Alfaro & Shigueto et al (2010) argue that small-scale fisheries management has generally been ignored (Kosamu 2015). In most developing countries, the understanding of the success factors of small-scale fisheries is still at a new stage, most of the success stories were reported from developed countries where small-scale fisheries were not dominant (Ratner et al 2012; Isaacs 2013). Small-scale bouke-ami fisheries for fringscale sardine species which belong to the family of *clupeidae* (Whitehead 1985; Froese et al 2017) are found in some of the world's waters and the populations are high. The exploitation of fringscale sardine has been started from the 10th century and was processed into fertilizers and oil. Fringscale sardine is one of the most important fish since the 16th century (Schwartzlose et al 1999; 2010). It was reported that the annual production of Fringscale sardine was 2.281.285 tons in 2005-2014. In 2015-2016, there was 2.3% of increase and decrease which equals to 2.238.903 tons and 2.289.929 tons respectively (FAO 2018).

Indonesia is the second largest capture fishieries country after China with an average production of 5.074.932 tons in 2005-2014, then 6.216.777 tons in 2015 and 6.109.783 tons in 2016. The production continued to increase but experienced a decrease at 1.7% in the last period (FAO 2018). In Indonesia, total production of *S. fimbriata* in 2016 was approximatelly 2.496273 tons. East Kalimantan Province contributed around 54.926 tons of the total production (MMAF 2019) and Kutai Kartanegara Regency contributed 1.642.1 tons (MFB 2018). The production value correlates with a high rate of exploration which may give an impact on the decrease of *S. fimbriata*'s population. Based on the results from several studies, this species is included in the IUCN red list or least concerned species (Munro 2018). Continous increase on the exploration of *S. fimbriata* has made smaller size fish being caught unintentionally and reduced the production rate. Previously, the decrease on the population rate as a result of early catch was balanced with recruitment and growth. However, overfishing and unlimited exploration of the fish resulted in the loss of chances to grow and recover (Fauzi 2010).

A study focusing on the biological aspect of certain species can scientifically describe the population status of a species (Abderazik et al 2016). Status, growth pattern and size distribution of fish are important data in sustainable fisheries management system (Nasir et al 2017). Referring to the aforementioned arguments, it is therefore necessary to conduct a study on the growth and mortality rate of *S. fimbriata*. It is hoped that the result of this study will become a reference for the government in managing and developing policy particularly for *S. fimbriata*.

Data and Research method. Data for this study is *S. fimbriata* (Whitehead 1985; Froese et al 2017). The fish were the results of boukeami catch along the Makassar straits. A 30-cm ruler and digital scale was used to measure the length and weight of the fish with the accuracy value of 0.1mm and 0.1g, respectively. Documentation was taken by a digital camera. Identification book was used as reference to identify *S. fimbriata*.

Duration and Research site. Field survey and sampling were conducted for 12 months starting from January to December 2017 along the Makassar straits up to the land area of Samboja Kuala, Kutai Kertanegara Regency, East Kalimantan Province, Indonesia on latitude 1°.1'22.22" S and longitude 117°.6'58.85" E. Data collection was carried out to analyze the growth parameter of *S. fimbriata*.

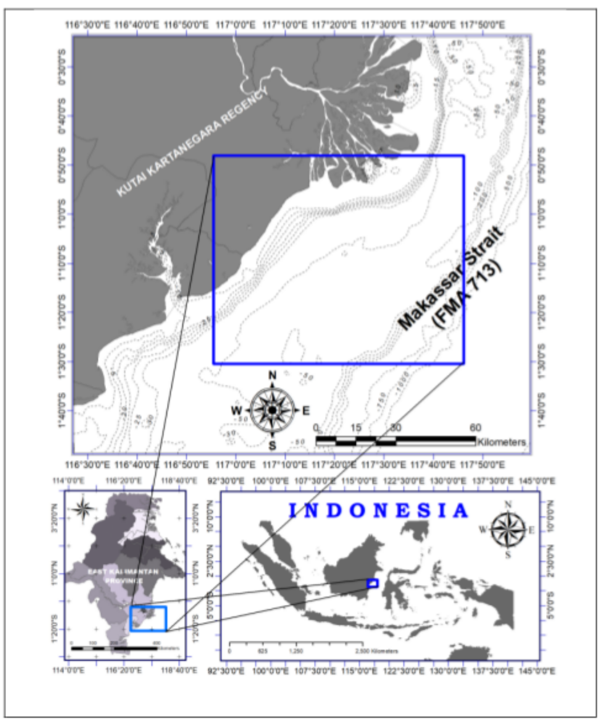


Figure 1. Research site

Data Analysis. There were two variables observed in this study, the first was total length (mm) and individual weight of each fish (gram). Simple FiSAT or FAO-ICLARM Stock Assesment Tools was used as the analisis tool as it only required data on the length frequency (Mancera and Mendo 1996; Amin et al 2001; Jagadis & Rajagopal 2007; Panda et al 2011; Chakraborty et al 2014; Hariyadi et al 2017).

Size structure. It refers to the composition size of *S. fimbriata* which were caught in Makassar straits. It described the frequency distribution based on the size. This data was then transferred to microsoft Excel 2010 to create the frequency distribution graphs.

The size at first capture. The size of at first capture (Lc) was measured based on the length of the fish. The computed length-at-first capture or $L_{50\%}$ was computed by plotting the percentage of cumulative frequency of captured fish with the total length size. The crossing line of the curve and 50% of cumulative frequency was the 50% of the length of captured fish. The infinity length (L_∞) was the average of the length of the fish when reaching the mature age. According to Pauly (1984) the computation for infinity length is as follow:

$$L_\infty = L_{maks} / 0.95$$

where:
L_{maks} = maximum length

The relationship between the length and weight of the fish. The relationship between the Length (L) and Weight (W) of the fish was referred to the following formula: (Effendie 1997; Fafioye and Oluajo 2005; Kalayci et al 2007):

$$\mathbf{W = a\,L^b}$$

where:
W = weight (g)
L = fork length (mm) a dan b = constanta

This analysis was carried out in order to know the relationship between the length and the weight of the fish. The value of b in the relationship became an indicator of the shape of the fish (lean, isometric or plump). If the value of b = 3, it means the growth of the fish is isometric where the increase of the length and weight is equal. If the value of b > 3 or b < 3 it means the growth is allometric where the increase of the length is slower or faster than the weight. Negative allometric is if b < 3 and positive allometric is if b > 3.

Growth parameters. The estimation of growth coefficient (K) and infinity length (L_∞) is based on Ford-Walford (Sparre dan Venema 1999). The regression of the length of the fish and the age is t-(Lt), where the length of the fish at certain age is t+1(Lt+1), therefore the equation of the growth parameter is $K = -Ln\ b$ dan $L_\infty = a/(1-b)$. The value of t_0 is the theroritical age of fish which is counted using empirical formula from Pauly (1983), the formula is as follows:

$$Log -(t_0) = -0.3922 - 0.2752 \; Log \; L_\infty - 1.038 \; Log \; K$$

The growth model of the fish as well as the relationship between age and the length of the fish can be described once the value K, L_∞ and t_0 are available. The values of growth parameters will then inserted in the growth model formula from Von Bertalanffy (1934), the formula is as follows:

$$L_t = L_\infty(1 - e^{-K(t-t_0)})$$

where:
L_t = the length at age-t (mm)
L_∞ = infinity length (mm)
K = growth coefficient (t^{-1})
t_0 = the "age" the fish would have had length zero if they had always grown according to the equation (t_0 generally has a negative value) (year)

The value of L_∞ and K were taken from the computation by using ELEFAN 1 method which is part of FISAT II program (Gayanilo, Venema and Pauly 2005).

Mortality rate. Estimation of total mortality (Z) is counted by using capture curve in which it is converted to length as in FISAT II program. The computation of Z is as follows:
$\mathrm{Ln}(Ni/\Delta ti) = a - b \cdot ti$

where:
Ni = the population in length class i
Δt_1 = time needed for the fish to grow through length class i.
t_1 = the age (or the relative age, computed with t0 = 0) corresponding to the mid-length of class i

According to the empirical formula from Pauly (1984) the natural mortality is consisted of variabels K per year, L_∞ (mm) and T (the average of water surface temperature in celcius). The empirical formula from Pauly (1984) is as fillows:

$$\mathrm{Log}\ M = -0.0066 - 0.279\ \mathrm{Log}\ L_\infty + 0.6453\ \mathrm{Log}\ K + 0.4634\ \mathrm{Log}\ T$$

where:
M = natural mortality coefficient
L_∞ = infinity length (cm)
K = Von Bertalanffy's growth coefficient
T = the average of water surface temperature in Makassar straits (FMA 713) which was 29.7 ^{o}C (Purwandani 2012; Labania et al 2018).

The F value (capture mortality can be estimated by subtracting total mortality (Z) from natural mortality (M), with the formula below:
Z = F + M, becomes: F = Z – M
where :
Z = total mortality coefficient
F = coefficient of capture mortality
M = Natural mortality coefficient
Based on the estimated value of the capture mortality rate (F) divided by the total mortality rate (Z), the rate of exploitation (E) can be estimated by the following formula:
E = F / Z
where :
E = The rate of exploitation or the share of mortality caused by capture
F = Mortality capture
Z = Total mortality
If the value of E = 0.5 indicates that the value is optimum (E_{opt}). This is based on the assumption that balanced results are optimum if F = M (Gulland 1983; Pauly 1983).

Recruitment Pattern. *Recruitment Pattern* is obtained by using the FISAT II program in the sub-program, which will show the percentage of recruitment for 12 months. The result of the estimation is shown on histogram by entering the values of L_∞, K and t_o which were previously calculated.

Results and Discussion. The structure of the length of *S. fimbriata* is displayed in the form of a histogram in Figure 2.

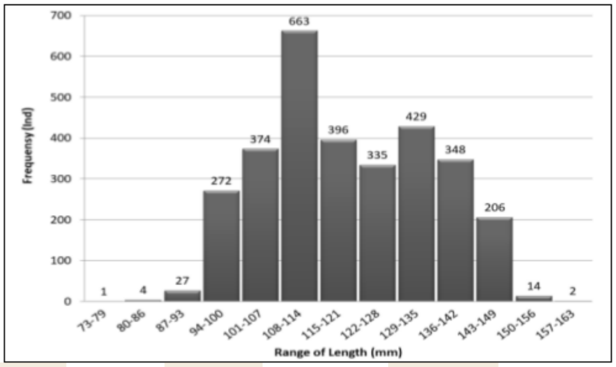
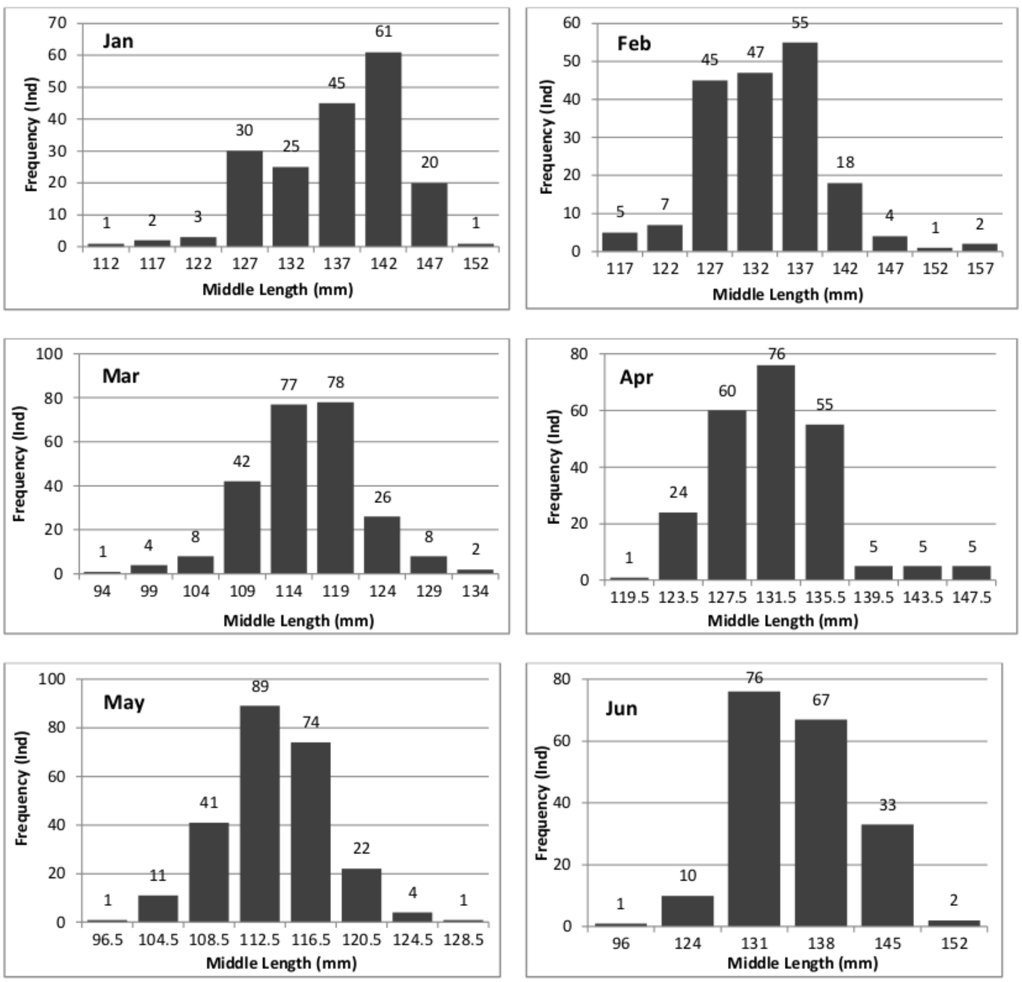


Figure 2. Range of length (mm) and frequency (individuals)



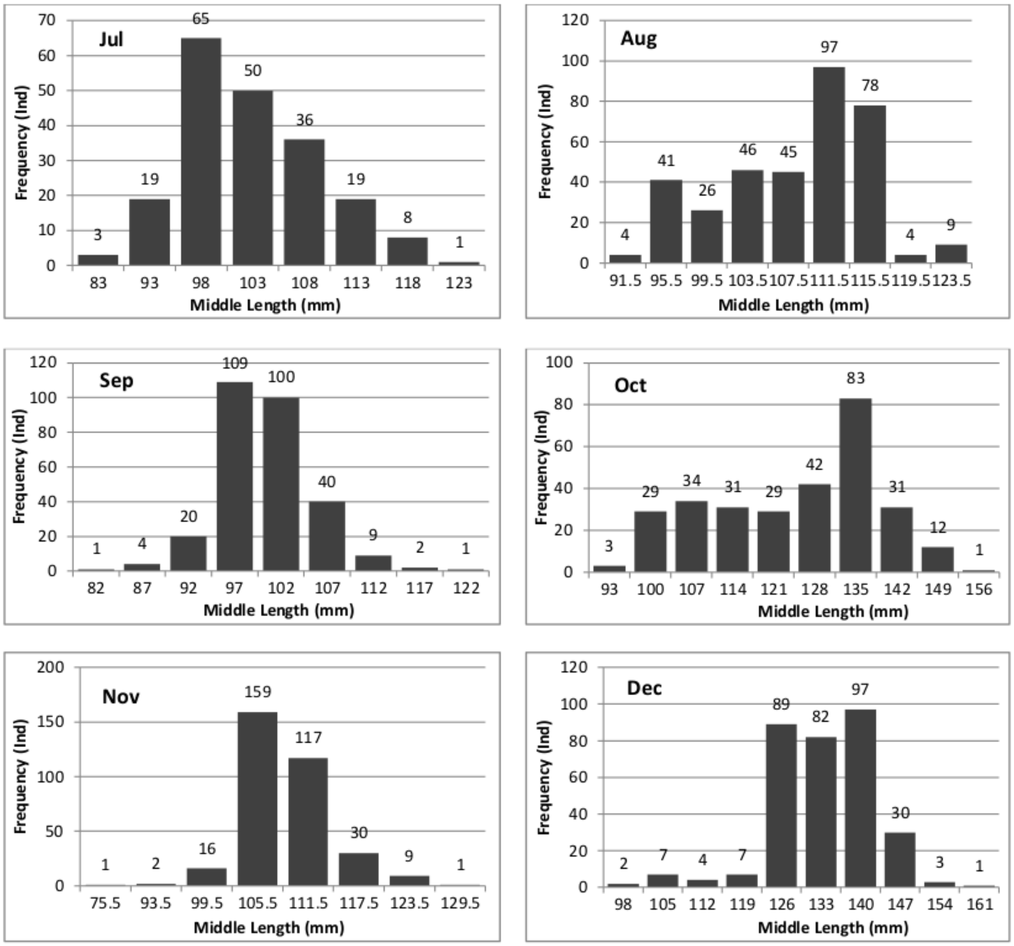


Figure 3. The length distribution of middle length of *S. fimbriata* from January to December 2017

Based on the analysis from Figures 2 and 3, there was a shifting phenomenon occurred in frequency of fish length class in several periods of months, there were March and May July - September and November. The fish samples were identified to have body lengths ranging from 80-156mm. From the 663 samples, the distributed lengths were 108-114mm. Based on the length size, the identified mode of length size class was in 90-120mm, which leads to small length class. It is assumed that this condition was resulted from the stage of adding new individuals (recruitment) and growing procees. This can be seen from the presence of small fish and the length-size class frequency distribution mode which was still in the short size class. Whereas in January, February, April, June, October and December the results lead to the distribution of fish at optimum captured size of 125-150mm. The results indicated that the growth time resulted in longer size of the fish and more adult S. fimbriata were caught in these periods.

Length-at-first-capture. The $L_{50\%}$ size was calculated by plotting the cumulative frequency with each fish length. The results of the first captured size calculation are shown in Table 1.

Table 1

The size of Length-at-first-capture			
L_{max} (mm)	L_∞ (mm)	½ L_∞ (mm)	$L_{50\%}$ (mm)
155	164.85	82.43	133.79

The optimum size for capture is very important and it was calculated by mode and average size of the fish caught ($Lc_{50\%}$). Size composition is one of the important information in assessing a population and stock (Saputra 2009). 663 samples were in size class 108-114mm and only one sample had size in class 73-79mm. The size at first capture ($Lc_{50\%}$) was 133.79mm.

The infinitive length value (L_∞) represented the estimation size of the fish that should be captured in a fishing ground. According to the results of the analysis, the value of $Lc_{50\%}$ was 133.79mm and the infinitive length value (L_∞) was 164.85mm, this illustrates that the value of $Lc_{50\%}$ was greater than ½ L_∞ (82.43mm), it means that the size of the S. fimbriata fish caught by bouke-ami fishermen was at an optimum size for capture.

Length-weight relationship. The relationship between length and weight of the fish shows different growth patterns. The assumption of growth patterns could be known by comparing values of b. The fish growth pattern in this study had dominantly negative allometric, it could be seen from the value of b which was less than 3 ($b < 3$). It indicated that the weight gre slower than length. The equation of the relationship of S. fimbriata was $W = 0.0037L^{1.819}$ where the range of b values was 1.64-1.96. Based on the value of b obtained and the results of t tests ($\alpha = 0.05$), the value of b indicated an allometric negative growth pattern which means the length grew faster than weight (Effendie 1997). The relationship of fish length and weight is shown in Figure 4.

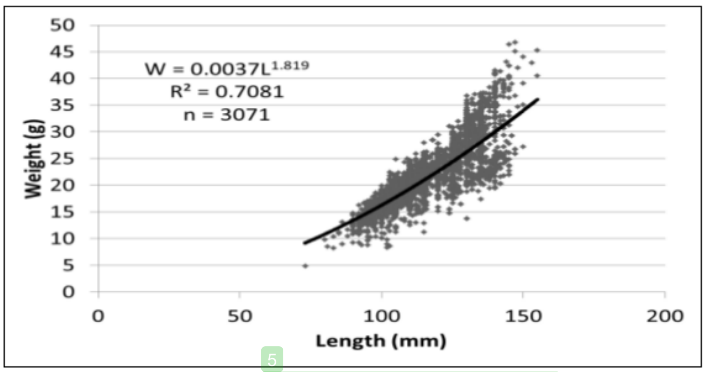


Figure 4. Length-weight relationship

Data on the relationship between the length and weight of fish had a determinant value (R^2) of 0.7081 (Figure 4). The value (R^2) shows degree relationship between length and weight, if the value of R^2 higher than 0.5 or close to 1, it indicates that variable weight can explained 0.7081 (R^2) or 70% by variable length. Different growth patterns were found in S. fimbriata that live in the Jakarta Bay $W = 0.0001714L^{2.9763}$ (Hutomo & Martosewojo 2008) and Palabuhanratu $W = 0.00000006L^{2.990}$ (Syakila 2008). It was reported that they had isometric. However, different data found in Kendari Bay where the fish had positive allometric $W = 0.008865L^{3.034}$ (Asriyana et al 2010). Difference in growth patterns could be caused by season, gender, area, fishing time, fishing vessel, availability of food, as well as the differences in the number and variation in fish size observed (Dulcic & Kraljevic 1996; Moutopoulos & Stergiou 2002; Kharat et al 2008).

Growth Parameters. The reference for Growth parameters is from the Von Bertalanffy equation, which uses the FiSAT II software and empirical formula (Pauly 1984). It is used to predict t_0, the growth coefficient (K), infinitive length (L_∞) and the theoretical age of fish when the length is zero (t_0). The results of the analysis show that L_{max} or maximum length at the time of sampling was 155mm. L_∞ obtained was 164.85mm. K value was 0.54 $year^{-1}$, and t_0 value was -0.72. The results of the growth parameter analysis by researchers in other waters show that in the Madura Probolinggo Strait was 212.5mm, this length was greater than the asymptotic length (infinitive) of S. fimbriata in the waters of Kendari Bay and Samboja Kuala Makassar Strait, with a growth coefficient (K) 1.2 $years^{-1}$. The results are presented in Table 2.

Table 2

Results of growth parameters of *S. fimbriata* in the other waters

Waters Area	L_∞ (mm)	K ($year^{-1}$)	Growth models	Sources
Kutai Kartanegara Makassar Strait	164.85	0.54	$164.85(1-e^{\{0,54(t-0,72)\}})$	Research present (2019)
Java Southern	200.8	0.50	$200.8(1-e^{\{0,50(t-0,36)\}})$	Hariyono 2017
Madura Strait Probolinggo	212.5	1.45	$212.8(1-e^{\{1,45(t-1.96)\}})$	Meyanti 2017
East Java Northern Tuban	212.0	0.81	$212.0(1-e^{\{0,81(t-0.22)\}})$	Muafi 2017
Sunda Strait	210.4	0.42	$210.4(1-e^{\{0,42(t-0.23)\}})$	Kusumowati 2016
Sunda Strait	169.58	0.30	$169.58(1-e^{\{-0.30(t-0.03)\}})$	Fauziyah 2015
Sunda Strait	175.10	0.24	$175.10(1-e^{\{-0.24(t-0.43)\}})$	Fauziyah 2014
Banten Bay	191.65	0.39	$191.65(1-e^{\{-0.39(t-0.25)\}})$	Simarmata 2013
Kendari Bay	199.50	1.78	$199.50(1-e^{\{-1.78(t-0.07)\}})$	Asriyana 2011
Kendari Bay	165.3	1.20	$165.30(1-e^{\{-1.20(t-0.155)\}})$	Asriyana et al 2010
Palabuhanratu Bay West Java	170.23	1.48	$170.23(1-e^{\{1,48(t-0.40)\}})$	Syakila 2009

There were significant differences when comparing the results of studies in other site with the results obtained in the waters of the Samboja Kuala Makassar Strait, particularly in the asymptote length (L_∞) which was more than 200mm (Hariyono 2017; Meyanti 2017; Muafi 2017; Kusumowati 2016) and coefficient values (K) which reflected to the maximum growth rate (above 1) such as data found in the Madura Probolinggo Strait (Meyanti 2017), Kendari Bay (Asriyana et al 2010; Asriyana 2011) and Palabuhanratu West Java (Syakila 2009) waters. It was assumed that these differences occurred because samples were taken from different location and aquatic environment. Fish species that live in different waters will experience different growths (Effendi 1997), important parameters such as fish size, structure and distribution of species always experience changes in response to environmental dynamics of anthropogenic activity and natural disturbances (Shelton & Mangel 2011; VanDover 2014; Micheli et al 2016). The Von Bertalanffy equation in this study was L_t = $164.85(1-e^{\{-0.54(t- 0.72)\}})$. The fish growth curves was created by plotting the age (t) and total length of fish (mm). In this study the fish age was ranged from 3 years 6 months to 5 years 5 months as shown in Figure 5.

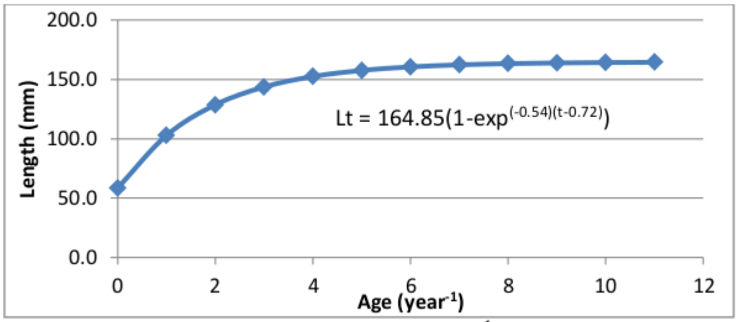


Figure 5. Relationship between age (yr^{-1}) and length (mm)

Mortality Rate. In a fish resource stock which has been exploited, it is necessary to differentiate between natural capture and mortality. In stock assessment, it is important to determine natural mortatility and capture related mortality. The total mortality rate (Z) is the sum of the capture mortality rate (F) and the natural mortality rate (M) (King 1995). In this study, the estimation of total mortality (Z) of S. fimbriata was based on a linearized curve. The curve was based on length data obtained an estimated total mortality rate (Z) = -b. The estimated natural mortality (M) of S. fimbriata was calculated by using the Pauly equation (1984). The *T* value was the average temperature of the Makassar Strait (Fisheries Management Area 713), it was 29.7°C (Purwandani 2012; Labania 2017). According to Pauly 1984, environmental factors that may affect the value of M are the average temperature of the waters as well as the infinity length (L_∞) and growth coefficient (K). The results of the analysis of the estimated mortality rate and rate of exploitation of S. fimbriata can be seen in Table 4.

Table 4

The values of Z, M dan F in other waters

Waters Area	Z (yr^{-1})	M (yr^{-1})	F (yr^{-1})	E (yr^{-1})	Sources
Kutai Kartanegara Makassar Strait	2.94	1.45	1.49	0.51	Research present (2019)
Java Southern	4.80	1.29	3.51	0.73	Hariyono 2017
Madura Strait Probolinggo	8.73	2.56	6.17	0.71	Meyanti 2017
East Java Northern Tuban	5.05	1.75	3.30	0.65	Muafi 2017
Sunda Strait	3.19	0.59	2.60	0.81	Kusumowati 2016
Sunda Strait	1.00	0.24	0.76	0.76	Fauziyah 2014
Sunda Strait	2.90	0.54	2.36	0.81	Fauziyah 2014
Palabuhanratu Bay West Java	8.53	1.15	7.38	0.87	Syakila 2009

Results from the analysis show that the total mortality rate (Z) was 2.94 $years^{-1}$, the capture mortality rate (F) was 1.49 $years^{-1}$, and it was greater than the natural mortality rate (M) of 1.45 $years^{-1}$. This result indicated that exploitation factor can be said to be in optimum condition, as the mortality rate due to capture was equal to natural mortality rate. The rate of exploitation was 0.51 which means that 51% of the mortality of S. fimbriata was caused by fishing activities. According to Sparre and Venema (1999), it can still be said to be optimum, as the value of optimum exploitation rate was 0.5. There were different conditions happened in other site, in which the level of exploitation indicates over fishing (Table 4).

According to King (1995), a decrease in fish stock can be caused by two factors, namely natural mortality and mortality due to fishing activity. Growth has a close relationship with

mortality, where high growth rate but short lifespan of fish indicates a fairly high mortality rate. Natural mortality is caused by various factors including predation, disease, stress, spawning, hunger and age, but the dominant factor of all is predation (Beverton & Holt 1957).
The natural mortality rate of a fish species varies, so does the mortality rate of the same species can be different depending on the predator density, competitors and environmental / habitat conditions. Mortality rate on catch caused by fishing activities, where the speed variation of the activities is strongly influenced by the type of fishing gear, the intensity of fishing, the strength of the engine of the ship used for fishing. These factors may correlated with fish size, fish behavior and habitat conditions (Saputra 2009).

Recruitment patterns. Based on the analysis, the recruitment patterns obtained are shown in Figure 6.

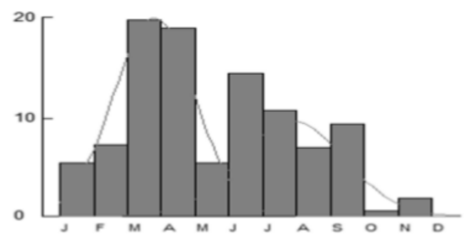


Figure 6. Recruitment pattern on 1 year

The highest percentage of recruitment per month was in March at 19.84%. The second were in April and June with values of 18.86% and 14.29% respectively. Meanwhile, in December it was absolute zero month time or there was no recruitment of new individuals, as can be seen in Figure 6. This data indicated that the pattern of recruitment of new individuals occured throughout the year, but the percentage varies and therefore fluctuations occured. The high recruitment in March and April were more influenced by spawning. The recruitment pattern is related to spawning time (Ongkers 2006) and fish migration which is influenced by various environmental factors such as fluctuations in water temperature, water level and light availability (Nachon et al 2016; Gosselin & Anderson 2017) and development factors including spawning, feeding ground and the search for protected areas (Lucas & Baras 2000; Chen & Yang 2005; Ahsan et al 2014; Nasir et al 2017). According to Romimohtarto and Juwana (2009), the spawning season occurs throughout the year and the peaks will occur in the transitional seasons of March and April and the beginning of the east season on June. There was a probability that the pattern of recruitment which uses the FiSAT program may have a result that was not in line with the reality. There were two assumptions could be made, the first is that all fish samples grow with a single set of growth parameters and secondly, once month in a year there is always zero recruitment (Pauly 1987 ; Gayanilo et al 2005). However, the model is still useful in predicting how the fish population in the natural environment will occur in one year (Sentosa and Djumanto 2010).

Conclusions. The results of this study showed an infinitive length of 164.85mm with the growth model L_t = 164.85(1-$e^{\{-0.54(t-0.72)\}}$). The fish growth curves was created by plotting age (t) and total fish length (mm). The data was obtained from catching the fish aged 3 years 6 months to 5 years 5 months. The nature of the fish growth was more of a negative allometric pattern. The capture mortality rate was 1.49 and it was equal to the natural mortality rate. The exploitation rate was at optimum condition with the E value of 51%. The most relative percentage of recruitment per month in March was 19.84%, and fewest in December there was no recruitment for new individual.

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