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Several Reproductive Aspects of Fringescale Sardinella (*Sardinella fimbriata*, Valenciennes, 1847) from Pekalongan National Fishing Port, Pekalongan Regency, Central Java

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ABSTRACT

The fringescale sardine (*Sardinella fimbriata*, Valenciennes, 1847) is one of the primary small pelagic fish commodities caught in the Java Sea. Overfishing and excessive exploitation can impact the sustainability of this fish resource in the wild. This study aimed to analyze various biological aspects of fringescale sardine, including sex ratio, growth patterns, condition factor, gonad maturity stage, size at first maturity, and size at first capture, which are essential for effective management efforts. Fish samples were collected from the Pekalongan National Fishing Port between June and September 2024. The specimens were obtained from the catches of fishermen operating in the Java Sea using mini purse seine fishing gear. The fish were measured, weighed, and dissected to obtain information on length, weight, sex, and gonad maturity stage. A total of 800 fish were collected during the study, consisting of 432 females and 368 males, revealing an unbalanced sex ratio. Both males and females exhibited negative allometric growth patterns, with females showing a higher condition factor compared to males. The catch was dominated by immature fish, and the size at first capture (Lc) was smaller than the size at first maturity (Lm) for both male and female fish.

INTRODUCTION

The fisheries management area of the Republic of Indonesia 712 (WPPNRI 712) has abundant potential for small pelagic fisheries. From 2003 to 2012, this region contributed 40.7% percent of the total fish catch in Indonesia **(Khatami *et al*., 2019)**. **Chodrijah and Hariati (2010)** stated that pelagic fish species that dominate the fish catch in the Java Sea are scad (*Decapterus* sp.), mackerel (*Rastilliger* sp.), bigeye scad (*Selar crumenophthalmus*) and fringescale sardine (*Sardinella fimbriata*). These small pelagic fish resources are generally caught by mini purse seine **(Mubarok *et al*., 2023)**

and as much as 89% percent of the small pelagic catch from the Java Sea land on the North Coast of Java, including the Pekalongan National Fishing Port **(Purwanto *et al.*, 2014)**.

Fringescales sardines is one of the small pelagic fish in the Java Sea with high potential since it is found as the main catch of the location especially in June **(Chodrijah & Hariati, 2010; Maulina *et al.*, 2019)**. However, in recent years, there has been a decline in this fish population in the surrounding waters, indicating pressure on this resource due to overexploitation and environmental changes **(Purwanto *et al.*, 2014; Nugroho *et al.*, 2017)**. Overexploitation of fish resources has caused the small pelagic fish resources in the Java Sea to decline because they have exceeded their sustainable potential **(Khatami *et al.*, 2019)**. Therefore, small pelagic fish resources in the Java Sea require management to maintain their sustainability.

Fish resource management requires information related to the biological aspects of fish because management requires a holistic approach **(Atmaja & Nugroho, 2017; Dutta & Hazra, 2017)**. Studies on reproductive aspects such as sex ratio, length-weight relationship, condition factor, gonad maturity level, size at first gonad maturity, and size at first caught are very important to inform fisheries management. A study by **Wujdi *et al.* (2016)** on lemuru (*Sardinella lemuru*) in the Bali Strait showed that the decline of lemuru population can be characterized by several biological parameters such as first-caught length and asymptotic length.

Studies related to fringescale sardine (*Sardinella fimbriata*, Valenciennes, 1847) have been conducted in various regions. Morphometric studies have been conducted by **Suleman and Djonu (2022)**. In addition, studies addressed the fishing season **(Chodrijah & Hariati, 2010)**, feeding habits **(Asriyana *et al.*, 2017)**, and fish vulnerability **(Puspita *et al.*, 2018)**. Biological studies of fringescale sardines have also been conducted by **Rilani *et al.* (2017)** in the Alas Strait, **Bintoro *et al.* (2019)** in the Bali Strait, **Bintoro *et al.* (2020)** in Trenggalek, and by **Ginzel *et al.* (2022)** in the Savu Sea. Although studies related to fringescale sardines' fish are very diverse and have been widely conducted, biological studies of fringescale sardines caught from the Java Sea and landed at Pekalongan have not yet been published. Such information is very important considering that increasing exploitation in the Java Sea. Therefore, the purpose of this study was to analyze several biological aspects of fringescale sardine landed at Pekalongan National Fishing Port. The objectives of this research support a goal of SDGs 14 to ensure the sustainable fisheries since the biological parameters from this research can be used to determine the minimum length of fringescale sardine harvested.

MATERIALS AND METHODS

Location and time

The fringescale sardine (*Sardinella fimbriata*, Valenciennes 1847) (Fig. 1) used in this study was collected from the fish auction site at the Pekalongan National Fishing Port. Fish sampling was conducted from June to August 2024, while length and weight

measurements as well as fish dissection were all carried out at the Pescica Marina Laboratory, Faculty of Fisheries and Marine Sciences, Universitas Jenderal Soedirman.

Procedures

The fringescale sardine samples were collected once per month using a random sampling method. The fish were taken from a single basket at the fish auction site of the Pekalongan National Fishing Port. The collected fish were then measured for their total length and standard length using a ruler with an accuracy of 1cm. Additionally, the fish were weighed using a digital scale with an accuracy of 0.01 grams. After measuring and weighing, the fish were dissected to determine their sex and gonadal maturity stage.

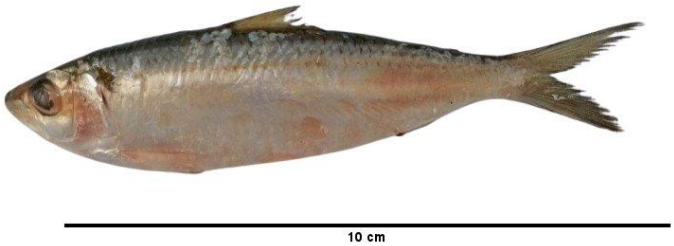


Fig. 1. Fringescale sardinella (*Sardinella fimbriata*, Valenciennes 1847)

Data analysis

Sex ratio

The sex ratio was calculated by comparing the number of male and female fish using the following equation:

$$N = J/B$$

Where, N is the male-to-female ratio, J represents the number of males, and B represents the number of females. The balance of male and female proportions in a population is determined through analysis using the Chi-square test.

Growth

Fish growth was analyzed based on the length-weight relationship using the following equation:

$$W = aL^b$$

Where, W is the fish weight, a and b are regression constants (intercept and slope), and L is the fish length. The constant b is used to determine the fish growth pattern. The value of b is analyzed using a t-test to determine whether $b = 3$ or $b \neq 3$. A value of $b = 3$ indicates isometric growth, whereas $b \neq 3$ suggests an allometric growth pattern.

Fulton's condition factors

Fish growth was also assessed through the condition factor, which represents the fish's fitness and overall condition for survival and reproduction. Fulton's condition factor was calculated using the equation proposed as follows:

$$Kn=100*W/L^3$$

Where, Kn is the Fulton's condition factor, W is the actual fish weight (g), and L is the length of fish (cm).

Gonadal maturity stage

The dissected fish were then visually examined for their gonadal maturity stage and compared with the gonadal maturity reference for the same species, which consists of seven gonadal maturity stages according to **Kudale and Rathod (2016)**. The description of the gonadal maturity stages is provided in Table (1).

Table 1. Description of gonadal maturity stages of Sardinella fimbriata **(Kudale & Rathod, 2016)**

Stage	Maturity Stage	Testes	Ovaries
I	**Immature** (Never spawned)	Smaller in size, whitish in colour, translucent and asymmetrical with long and thin vas deference.	Small, thread-like, translucent and have two small asymmetrical clear lobes with long and thin oviduct. Ova were not visible to the naked eye. Ova diameter ranged between 0.053 to 0.131 mm
II	**Immature** (Developing/ Maturing (Virgin)/ Recovered spent or Rematuring stage	White in color, flattened, translucent/ opaque, extends about ½ length of the body cavity with little reduced vas deference.	Yellowish in color, occupies about ½ length of the body cavity. Ova diameter ranged between 0.133 to 0.159 mm
III	**Developing**	Thickened and white in color, translucent, extended less than two third length of the body cavity with wide and reduced vas deference.	Turgid, opaque and yellowish in color with granular appearance. Ovaries occupied about two third length of the body cavity. Oviduct was reduced. Ova

			diameter ranged between 0.161 to 0.176 mm.
IV	**Maturing**	Massive in size, creamy whitish in color. Acquired more than two third length of the body cavity with very much reduced vas deference.	Ovaries were reddish yellow in color. Blood vessels prominent, Ova were semitransparent and spherical. Ova diameter ranged between 0.180 to 0.201 mm.
V	**Mature**	Prominent in size, acquired more than ¾ lengths of the body cavity and milt starts oozing out if pressure is applied on the abdomen	Ovaries large, orange colored and fully developed. Extended almost in the entire body cavity. Ovaries were filled with numerous, yellowish ova. In mature condition the eggs were large and visible with naked eye. Size of ova varied between 0.204 to 0.295 mm
IV	**Ripe**	Testes were very thick, flattened, turgid and creamish white in color. More Prominent in size (extensive), acquired full length of the body cavity and shows milting. Milt oozes out from the cut ends of the testes in the copious amount	Fully filled with yolk, free and opaque large eggs, those were almost ready for liberation. Size of ova varied between 0.322 to 0.512 mm
IV	Spent	Appeared shrunken and transparent	Partially and fully spent ovaries were found. At this stage few residual eggs were seen. The fully spent ovaries were flabby, contracted and empty.

Length at the first maturity

The size at first maturity is defined as the size at which 50% of the observed samples have reached gonadal maturity stages IV and V. These data were analyzed using the Spearman-Karber method **(Udupa, 1986)** based on the following equation:

$$m = Xk + \frac{X}{2} - (X\sum P_i)$$

The length at first gonadal maturity was obtained by determining the antilogarithm of the m value, where Xk is the logarithm of the length at which the last fish reaches gonadal maturity, x is the logarithmic difference of the median, p_i is the proportion of mature fish in the i-th length class.

Length at the first capture

The size at first capture was determined by plotting the cumulative frequency of each fish length class, resulting in a standard logistic curve with a sigmoid shape. The calculation of the length at first capture follows the method described by **Sparre and Venema (1998)** using the following equation:

$$SL = \frac{1}{1 + \exp^{(S_1 - S_2 * L)}}$$

Where, SL represents the estimated number of fish captured, L is the midpoint of the length class interval, and S_1 and S_2 are constants used in the logistic curve equation.

RESULTS

1. Sex ratio

A total of 800 fringescale sardine (*Sardinella fimbriata*) were collected during the study, with females (432) outnumbering males (368). The number of female fish exceeded the number of males each month, except in August (Fig. 2). The sex ratio between male and female fish during the study was 1:1.17. The Chi-square test results indicated that the male-to-female proportion was not balanced (1 ≠ 1), with females being more abundant than males.

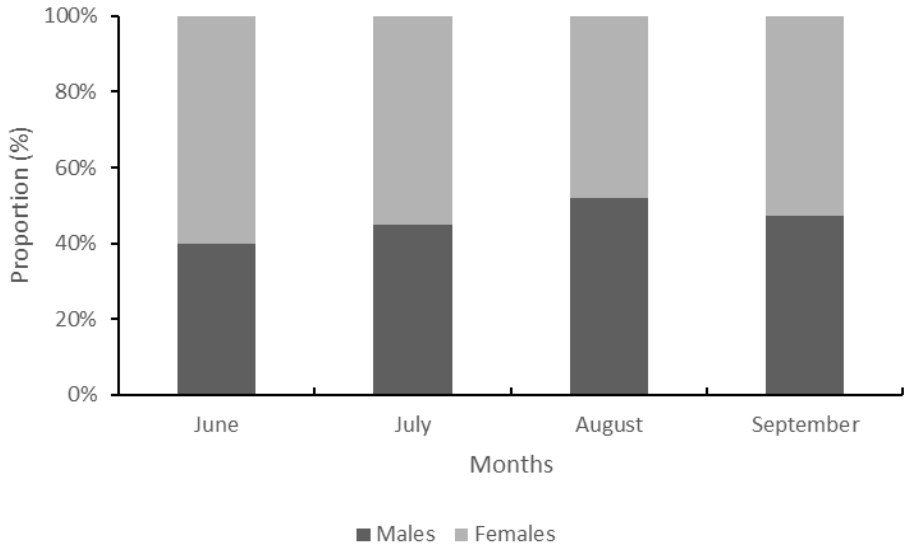
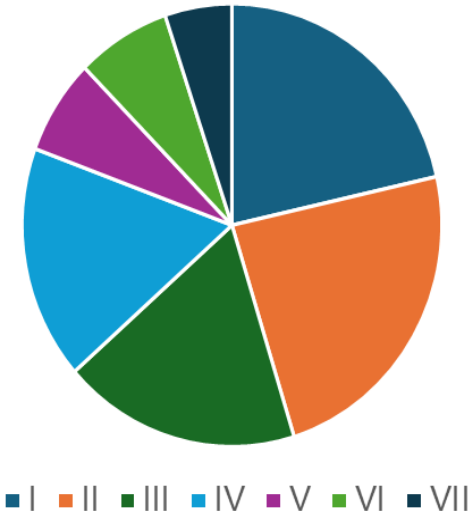
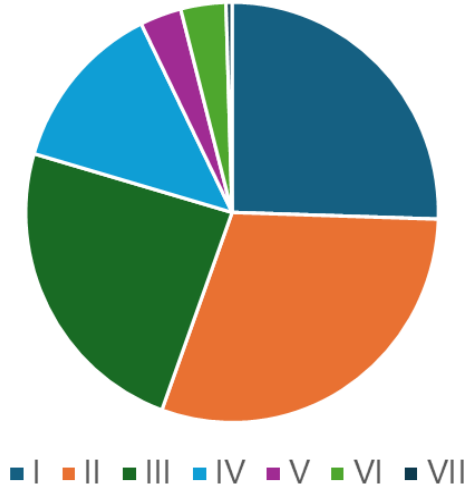


Fig. 2. Males and females' proportions of fringescale sardine from Pekalongan National Fishing Port from June to September

The composition of gonad maturity levels of female (Fig. 3A) and male (3B) fringescale sardine showed that both male and female fish were dominated by fish that had gonad maturity levels I-IV (immature) which reached 80% in female fish and 93% in male fish with the highest proportion found in gonad maturity level II fish. Female and male fringescale sardine found to be gonadally mature (TKG IV and V) were found in low proportions both in females (<10%) and <5% in males.



(A)



(B)

Fig. 3. Proportion of gonad maturity level of fringescale fish female (A) and male (B) from Pekalongan National Fishing Port

2. Growth

The results of the length-weight relationship analysis of male and female fish are shown in Table (2). The results of regression analysis of length and weight of female and

male fringescale sardine show that there is a strong correlation between length and weight since it accounted for 0.90 for females and 0.94 for males. The contribution of length to weight of the fringescale sardine is shown by the coefficient of determination in which 90% in female and 94% in male. The equation obtained from the regression analysis results in female fish is $W= 0.0198L^{2.71}$ and male fish with the equation $W= 0.0232L^{2.63}$ (Figs. 4, 5).

The b value (slope) of the regression results in fish can show the growth pattern in fish. Female fish had a b value of 2.71 and male fish had a b value of 2.63. The results of the t test on the value of b with a *P*-value = 0.05 show that the value of b is not equal to 3 ($b \neq 3$). **Jisr *et al*. (2018)** stated that the value of $b < 3$ indicates a negative allometric fish growth pattern or fish length growth is faster than weight growth.

Table 2. Length-weight regression of Fringescale *Sardinella* (Valenciennes 1847)

Sex	a	b	R2	R	Growth pattern
Female	0,0198	2,71	0,815	0,90	Negative Allometrics
Male	0,0232	2,63	0,877	0,94	Negative Allometrics

The value of b can be used to estimate the condition factor of fish. In this research, the condition factor for females ranged from 0.573-1.093; while for male, it ranged from 0.730-1.107. Overall, the mean condition factor from June to September for female (0.92) are greater than that recorded for the male (0.89). The mean value of the condition factor of female fringescale showed a declining trend from June to September, with the peak of the condition factor in July. In contrast, the condition factor of males increased from June to August and experienced a small decline in September, with the highest value recorded in August. Several findings about growth pattern and the condition factor of fringescale that have been reported from other locations are presented in Table (3).

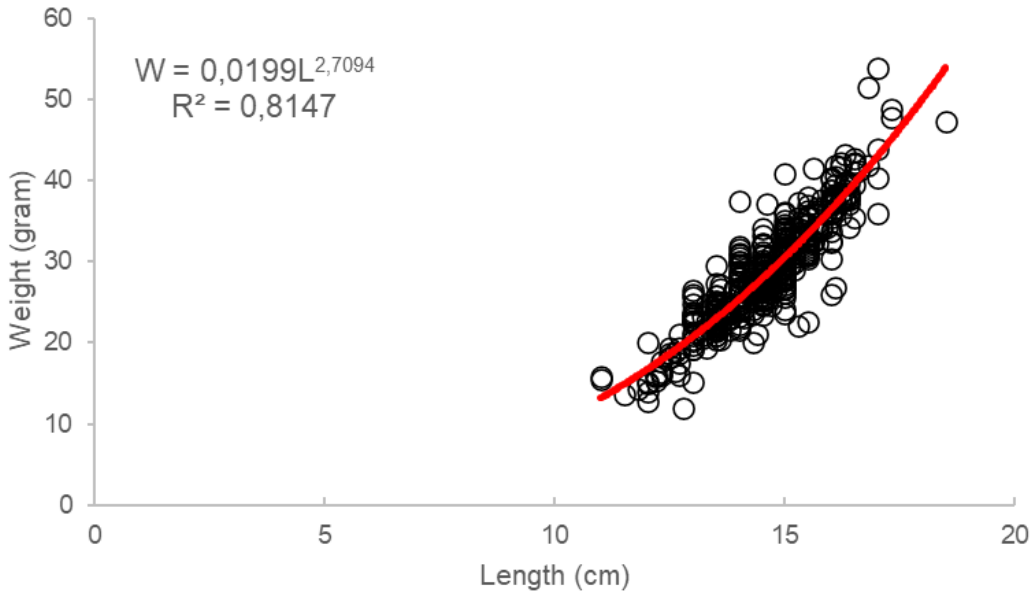


Fig. 4. Length-weight relationship of females fringescale sardines from Pekalongan National Fishing Port

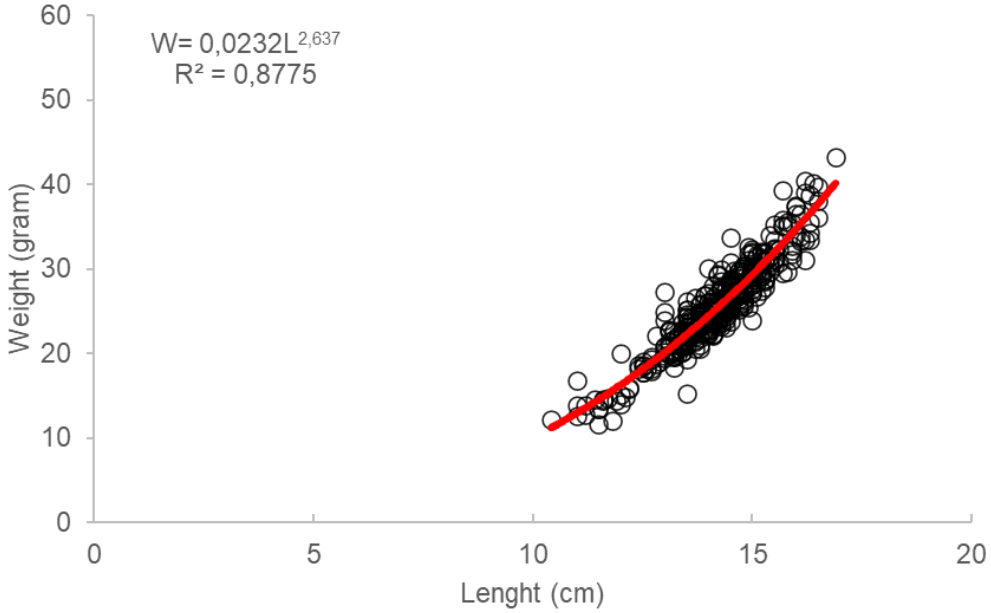


Fig. 5. Length-weight relationship of males fringescale sardines from Pekalongan National Fishing Port

Tabel 3. Range and means of fringescale sardine condition factor (*Sardinella fimbriata*, Valenciennes, 1847)

Months	Females			Males		
	Ranged	**Mean**	**SD**	**Ranged**	**Mean**	**SD**
June	0.573-1.206	0.925	0.098	0.730-1.206	0.860	0.066
July	0.699-1,148	0.945	0.088	0.622-1.054	0.887	0,067
August	0.607-1.364	0.904	0.060	0.736-1.264	0.929	0,085
September	0.791-1.093	0.902	0.048	0.709-1,107	0.878	0,054

SD: Standard Deviation.

Tables (4, 5) represent the overall trend of mean condition factor in male and female which increased with the gonadal maturity although a slight decrease is observed. Comparation of mean condition factor between male and female showed that female's condition factor outweigh male's mean condition factor. Tables (4, 5) also revealed that the highest value of condition factor in female was found in the gonadal maturity stage 6 which accounted for 0.94; while for female, it was found in the first gonad maturity stage with a value of 0.93

Table 4. The condition factor of female fringescale sardine based on gonad maturity stages

Gonadal Maturity Stage	Condition Factor	
	Range	Mean±SD
1	0.09-0.13	0.93±0.12
2	0.08-0.14	0.92±0.09
3	0.10-0.13	0.91±0.09
4	0.09-0.12	0.91±0.09
5	0.10-0.14	0.91±0.06
6	0.11-0.15	0.91±0.09
7	0.12	0.91±0.08

Table 5. The condition factor of male fringescale sardine based on gonad maturity stages

Gonadal Maturity Stage	Condition Factor	
	Range	Mean±SD
1	0.74-1.09	0.88±0.07
2	0.62-1.26	0.90±0.09
3	0.78-1.02	0.88±0.05
4	0.71-1.00	0.89±0.06
5	0.81-1.11	0.90±0.08
6	0.83-1.24	0.94±0.11
7	0.89	0.89±0

3. Length at the first maturity and length at the first capture

The results of the analysis of the length of the first maturity fish in female fringescale sardine showed that the fringescale sardine fish collected from Pekalongan VAT during the study were on average gonadally mature at 16.8cm, while the first size of fringescale sardine caught was 14.05cm (Fig. 6). The length of the first maturity male fringescale sardine in this study was 14.66cm, and the length of the first caught male fringescale sardine (Lc = 13.65cm) was smaller than the size of the first time the fish matured (Lc < Lm) (Fig. 7). **Bintoro *et al*. (2019)** reported that in the Bali Strait, this fish had smaller Lc and Lm values of 10, 44cm (Lc), 11.95cm (Male Lm), and 10.79cm (Female Lm). In the Trenggalek River, Indonesia, the Lc value of this fish was reported.

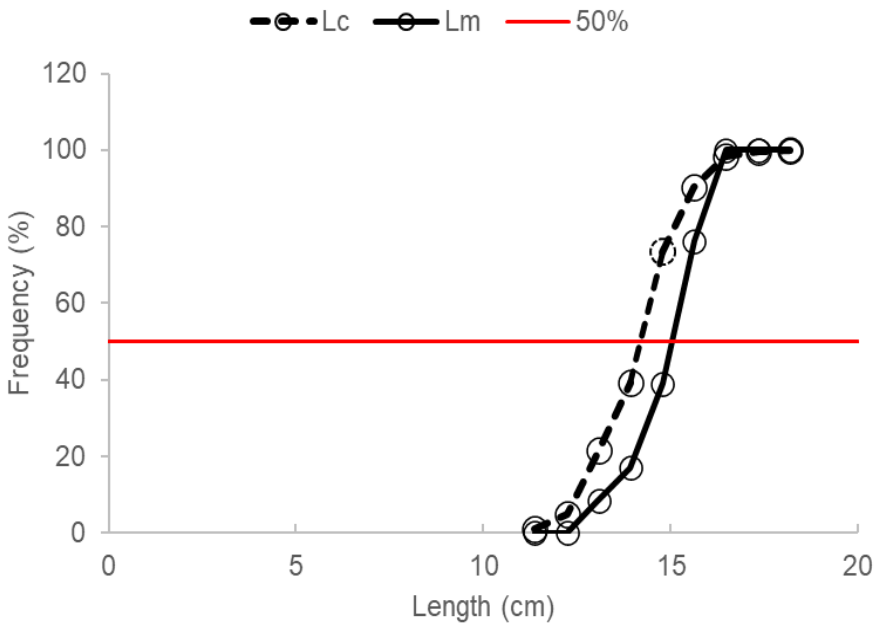


Fig. 6. Length at the first capture of female fringescale sardine

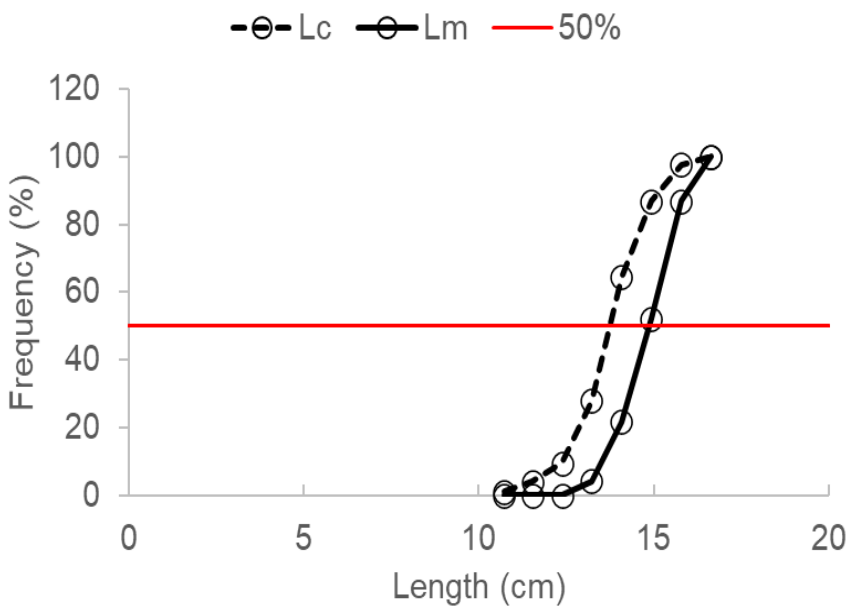


Fig. 7. Length at the first capture of male fringescale sardine

DISCUSSION

The sex ratio of fringescale sardine (*Sardinella fimbriata*) collected from the Pekalongan National Fishing Port showed an imbalance between males and females, with a higher proportion of females. This female-biased ratio is influenced by several factors, including environmental conditions. **Nikolsky (1969)** stated that when food is abundant, females tend to dominate the population. In addition, reproductive aspects may also contribute to the result, as female reproduction is not strictly dependent on the presence of males but is highly influenced by favorable environmental conditions **(Oliveira *et al.*, 2012)**. Therefore, the observed sex ratio in this study may indicate that the environment and food availability at the fishing ground—the Java Sea—remain suitable for the growth of fringescale sardine.

In other waters such as Kawar, Karnataka, India, **Kudale and Rathod (2016)** and **Bintoro *et al.* (2020)** in Prigi Water reported a balanced sex ratio in fringescale sardine populations. While no specific data on the sex ratio of *S. fimbriata* in the Java Sea is available, **Kartini *et al.* (2017)** observed a similar pattern in the lemuru (*Amblygaster sirm*), another Clupeidae species, with fewer males than females. A predominance of females in a fish population can indicate a favorable condition for population sustainability. A population can remain viable if the proportion of females is equal to or greater than that of males **(Efizon *et al.*, 2021)**

The relative condition factor observed throughout the study also reflected a higher female sex ratio from June to September. The average condition factor values for females were higher than for males, indicating that females tend to have greater body weight.

Similar results were reported for the lemuru (Clupeidae) in the Sunda Strait **(Kartini *et al.*, 2017)**. Differences in condition factor between sexes can be attributed to feeding activity, gonadal development, and other biological factors **(Jusmaldi *et al.*, 2023)**. The condition factor (Kn) for both sexes was below 1 (Kn < 1), although values close to 1 still suggest that the fish collected from the Pekalongan Port were in relatively good condition, indicating that the habitat supports fish health **(Parawangsa *et al.*, 2021)**. Although fish are considered to be in good condition when Kn ≥ 1 **(Jisr, 2018)**, both sexes in this study showed Kn values approaching 1.

The Kn pattern in females showed a declining trend corresponding with increasing gonadal maturity. This can be explained by the influence of reproductive activity on Kn values. Fish tend to reduce feeding activity and utilize internal lipid reserves during the spawning period, which results in a lower condition factor **(Brosset *et al.*, 2016)**. **Nayak *et al.* (2021)** also noted a negative correlation between gonadal maturity and condition factor, although this relationship may vary across species. **Mozsar *et al.* (2025)** concluded that condition factor values are species-specific.

Regression analysis for both male and female fringescale sardines revealed a strong coefficient of determination and a high correlation. More than 80% of fish weight variation was explained by length for both sexes. The correlation coefficients were also high, with values of 0.90 for females and 0.94 for males. The regression results showed a negative allometric growth pattern for both sexes, with b = 2.71 for females and b = 2.63 for males. This indicates that length increases faster than weight. Similar patterns were found in fringescale sardines from the Sawu Sea **(Ginzel *et al.*, 2022)**. Allometric growth in fish can be caused by ontogenetic development **(Fu *et al.*, 2016)**, changes in gonadal maturation **(Bintoro *et al.*, 2019)**, or external factors such as food availability and water quality **(Nur *et al.*, 2023)**.

Based on the length at maturity (Lm), 49.18% of male fringescale sardines captured had reached sexual maturity, whereas 50.82% of females caught had not. Regarding the length at first capture (Lc), 65.74% of females caught exceeded this length, while 34.26% were caught below it. The comparison of Lc and Lm values suggests that most fish caught had not yet reached gonadal maturity (Lc < Lm), indicating a potential for growth overfishing **(Cánovas-Molina *et al.*, 2021; Ben-Hasan *et al.*, 2021)**. If fish are caught before spawning, the sustainability of the stock is jeopardized **(Zamroni *et al.*, 2019)**. **Khatami *et al.* (2019b)** reported that the exploitation status of this species in the Java Sea in 2019 was already overexploited. **Ginzel *et al.* (2022)** noted that the peak recruitment of fringescale sardines (*S. fimbriata* Val. 1847) occurs in May and August, although no similar data are currently available for the Java Sea population. Additional reports state that most of the fringescale sardines in the Java Sea are caught in July, June, and from September to November **(Chodrijah & Hariati, 2010)**.

CONCLUSION

The fringescale sardine (*Sardinella fimbriata*, Valenciennes 1847) collected from Pekalongan National Fishing Port has an unbalanced proportion of males and females. Male and female fringescale sardine have a negative growth pattern which is length that is faster than their weight with the condition factor of females being larger than males. Male and female fringescale sardine caught are dominated by juveniles with the size of the first time caught that is smaller than the size of the first time the fish matures gonad. These conditions indicate that fringescale sardine are under threat of growth overfishing.

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