Biological aspects of long tongue sole, *Cynoglossus lingua*, in the South Sea of West Java, Indonesia

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Abstract. The waters of Pangandaran and Cilacap, Central Java, Indonesia have abundant fish resources consisting of large pelagic, small pelagic, demersal and crustacean. One of the fishery resources is *Cynoglossus lingua,* a demersal fish species that has important economic value. The aim of this research was to examine the biological aspects of *C. lingua* and to determine the level of its utilization and management in the Cilacap and Pangandaran waters. The research was carried out for 90 days at 3 locations: Cilacap Waters, Central Java; Bojong Salawe; and Cikidang, Pangandaran, West Java. Data was obtained by taking fish samples and measuring length and weight, sex ratio, gonad maturity level (GML), length at first capture (Lc), length at first mature (Lm). The results of the research on 1,450 samples showed that fish with negative allometric growth characteristics were obtained. From the chi-square test it was found that there was a significant difference between female and male *C. lingua*. The gonad maturity level (GML) was dominated by GML II and GML III. The first maturity gonads' size (Lm) was 12.86 cm, and the size at the first catch (Lc) was 33.73 cm, thus, Lc>Lm, which means that the caught fish specimens have already spawned. To ensure the sustainability of *C. lingua* whose utilization level has entered the overfishing category, management needs to be carried out in accordance with information on biological and fishery aspects.
Key Words: total allowable catch, MSY, over exploited, overfishing.

Introduction. Indonesia has been dubbed a maritime country because its sea area is wider than its land area (Nugraha & Mulyono 2017; Hermawan & Nugraha 2022). Fishery is one of the sectors that is relied upon for Indonesia's future development, because it can have an economic impact on some of Indonesia's population (Iyan 2014). Pangandaran and Cilacap waters have abundant fish resources (Anas et al 2016). Potential fish resources in Pangandaran Regency consist of large pelagic, small pelagic, demersal fish and crustaceans (Kartika et al 2020). Cilacap Regency also contributes the higher volume of marine fisheries production in the Central Java Province compared to other regencies/cities (Lestari et al 2016).

One of the fisheries resources in the waters of Cilacap and Pangandaran is the long tongue sole (*Cynoglossus lingua*). *C. lingua* is a demersal fish species that has important economic value (Sulistiono et al 2011). This fish is included in the *Cynoglossidae* family which actively forages at night (nocturnal) (Alina & Madduppa 2020; Gustiarisanie et al 2017) and is often found in waters and estuary areas or at river estuaries with sandy or muddy sand substrates (Hedayati et al 2017). The movement of this fish is passive, so its distribution is not too wide. Its metamorphosis is unique: in the larval stage it is symmetrical, then, as it progresses to the juvenile phase, it becomes asymmetrical. Its pectoral fin is degraded, while the dorsal fin and anal fin are connected to the caudal fin

(Kramer 1991; Petitgas et al 2013). Fishing efforts carried out by fishermen to date have not taken into account the size of the fish population and its evolution, which can result in a decrease in catches. Hence the resource management efforts of *C. lingua* are very necessary (Sulistiono et al 2011). The aim of this research was to examine the biological aspects of *C. lingua* and to determine the level of its utilization and management in the Cilacap and Pangandaran waters. The results of this research can provide knowledge for researchers and be used as secondary data or scientific information on the biological and fishery aspects of *C. lingua* in Cilacap and Pangandaran waters.

Material and Method. The research was carried out for 90 days, starting from March 8th to May 5th, 2021, in the waters of Cilacap, Central Java, Bojong Salawe and Cikidang, District Pangandaran, West Java. Figure 1 shows the location of the *C. lingua* samples collection point, considering the high probability of fish presence in Cilacap and Pangandaran waters. The tools and materials used in this research include: a ruler with an accuracy of 0.1 cm, a scale with an accuracy of 0.1 g, a dissecting set, a GPS, a digital camera, and a questionnaire sheet.

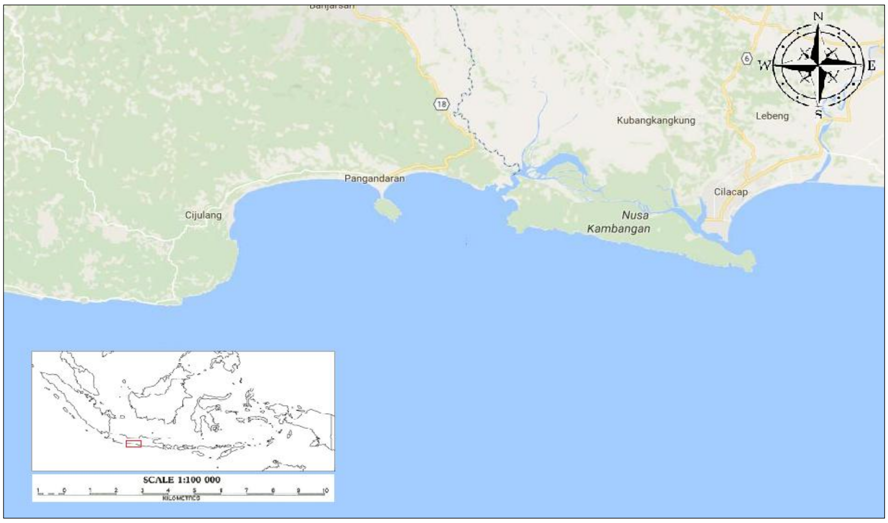

Figure 1. Map of research location.

Method of collecting data. The data collection method used was a direct survey, by conducting field observations of *C. lingua* samples. Both primary and secondary data were used. Fish samples were taken from fishermen's catches in three sampling sites, namely Cilacap, Bojong Salawe and Cikidang Pangandaran. Primary data on length and weight, sex ratio, gonad maturity level (GML), length at first capture (Lc), length at first maturity (Lm) was obtained from fish samples, directly by taking measurements (Suharti et al 2023). In this research, secondary data on *C. lingua* catches originate from previous research and reference books.

Data analysis methods

Long frequency distribution. The steps to analyze length frequency data were: a) Determining the number of class intervals needed; b) Determining the frequency class and entering the frequency of each class by entering the length of each fish sample in the specified class interval, and c) Determining the length frequency distribution in the same class interval and then plotting it on a graph. The shift in the length frequency distribution describes the number of age groups (cohorts) present.

Length weight relationship. The length-weight relationship (LWR) shows the relative growth and it might change over time (Shasia et al 2021), with the environmental conditions and food availability (Meretsky et al 2000; Bariddah et al 2020). Each fish sample was measured for length and weight. The total body length of the fish was measured from the mouth to the tail. Fish weight was measured using a digital scale using the formula (Muhotimah et al 2013):

$$W = aL^b$$

Where:
W - weight (g);
L - length (cm);
a - intercept;
b - slope.

A linear regression equation of the form y = a' + bx was obtained from the following equation:

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

The linear equation was plotted using an MS-Excel computer program to estimate the values of the constant (a'), slope (b), and the coefficient of correlation (r) of the LWRs and the significant differences. The fish growth was categorized using b values; where b=3, the fish attains an isometric growth; where b<3, the fish indicates a negative allometric growth; and where b>3, the fish indicates a positive allometric growth (Lim et al 2013; Hermawan et al 2023).

According to Effendie (1979), the b values can be interpreted as follows:
1. When b<3, then the increase in length is faster than the increase in weight (negative allometric);
2. When b>3, then the increase in weight is faster than the increase in length (positive allometric);
3. When b=3, then the increase in length and increase in weight are balanced (isometric).

Sex ratio. Knowledge of the sex ratio imbalance is very necessary to predict population growth (Wardhani et al 2024). It is calculated by the ratio of the number of male and female individuals in a population (Fauzi & Corebima 2016; Saputra et al 2009). Ideal sex ratio are generally supported by environmental and habitat conditions optimal for the survival of organisms (Widyastuti 2017). Variations in sex ratio often occur due to 3 factors: reproductive behavior, environmental conditions and fishing (Arnenda et al 2019). Determining whether the male and female sex ratio is balanced or not is done by Chi-Square testing (Omar 2013).

$$SR = \frac{\sum F}{\sum M}$$

Where:
SR - sex ratio;
Σ F - number of female fish;
Σ M - number of male fish.

The real difference between the numbers of males and females, is determined through testing and the 'χ^{2}' $_{test}$ (chi square) with the formula (Maung et al 2019):

$$X^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}$$

Where:
X2 - chi square value;
O - frequency of male or female fish observed;
E - expected frequency of male or female fish.

Gonad maturity level (GML). The basis used to determine GML morphologically is the shape, length, color, and development of the gonadal content. The determination of the GML of *C. lingua* is conducted by referring to five levels of classification of gonadal maturity of marine fish, and by comparing the shape and characteristics of gonadal development with the morphological literature of fish gonads (Effendie 1997). If fish are caught before the gonads are mature, or have not had time to spawn, this will affect recruitment in these waters (Hasibuan et al 2018). In general, there is a correlation between length and GML of fish. The larger the size of the fish, the more developed the level of gonad maturity. GML is observed morphologically the examination of the colour, shape, length and weight, and the development of gonad contents (Achmad et al 2019). The next process is determining the GML on the gonads obtained from the fish that have been studied. The data required is gonad size and gonad morphology (Hukom et al 2017; Sulistiono et al 2006). Observation of the level of gonad maturity is based on the standard for determining the level of GML, based on morphological modifications from Cassie (Soenanthi 2017).

Length at first capture (Lc). The size at first capture (Lc) is used as a reference in determining fishery resource management (Iswara et al 2014) using the frequency distribution of fish length and the normal equation approach (Ernaningsih 2016). Sparre & Venema (1998) described the length at first capture using the formula:

$$SL\ est = -\frac{1}{1 + \exp\ (S1 - S2*L)}$$

$$L\ 50\% = -\frac{S1}{S2}$$

$$Lc = \frac{S1}{S2}$$

Where:
SL est - logistic curve;
S1 and S2 – constants.

Length at first mature (Lm). The size of the first gonads maturity (Lm) is obtained by plotting the cumulative percentage of fish with mature gonads against the body length (Barokah et al 2016). Lm is useful in the fish reproductive strategy, in addition to sex ratio, spawning period and type, oocyte development and fecundity (Wardhani et al 2024). Determining Lm can use the frequency distribution of the specimens that have matured gonads. The Lm was calculated using the Spearman-Karber equation (Islamiati et al 2018):

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

$$M = \text{antilog}\ (m \pm 1.96 \sqrt{x^2 \sum \frac{pi*qi}{ni-1}})$$

Where:
m - logarithm of the length class at its first maturity;
d - logarithm of the increase in the median length;
k - number of length classes;
xk - logarithm of the median length where the fish is 100% gonadal mature (or where pi=1);
pi - ratio of the mature fish in the length class i to the number of fish on the length interval i;
ni - number of fish in the length class i;
qi - 1 – pi;
M - length of fish at first maturity equal to anti-log m, if $\propto$=0.05, then the confidence interval is 95% of m.

Catch per unit effort (CPUE). The data required to calculate CPUE are catch and fishing effort data. Fishing effort is the amount of fishing gear used over a specific time period, which can be measured by the number of vessels, the number of fishing trips, and the length of time the gear is operated per setting or per hour of net drag. Annual production data is divided by the annual fishing effort to obtain CPUE. The CPUE formula is as follows (Tresnati et al 2012):

$$CPUE_t = \frac{Catch_t}{Effort_t}$$

Where:
$CPUE_t$ - CPUE over a period t (kg $trip^{-1}$);
$Catch_t$ - catch over a period t (kg);
$Effort_t$ - fishing effort over a period t (trips number).

Utilization level analysis. The utilization level shows the amount of production capacity achieved, compared the sustainable potential (MSY). The utilization rate was obtained by the formula (Abdullah et al 2015).

$$\text{Utilization level (\%)} = \frac{Yi}{MSY} \times 100$$

Where:
Yi - number of fish caught in year i;
MSY - maximum sustainable yield.

Results and Discussion

Biological aspects. Morphologically, *C. lingua* is characterized by: an elongated body, a flat body shape (lateral), both eyes are on one side of the body located in the middle, mouth is small in the inferior part (bottom), round snout, dorsal fin starting from in front of the eyes and continuing to the tail, and reddish brown with dark spots (Figure 2).

Figure 2. *Cynoglossus lingua.*

The number of *C. lingua* fish samples obtained was 1,450: 750 from Cilacap, 350 from Bojong Salawe, and 350 from Cikidang. Maximum and minimum length and weight of *C. lingua* are presented in Table 1.

Table 1

Length and weight of *Cynoglossus lingua*

Research location	*Number of samples*	*Length*		*Weight*	
		Max.	*Min.*	*Max.*	*Min.*
Cilacap	750	40	11	316	8
Bojong Salawe	350	47	13.5	734	24
Cikidang	350	47	12.5	734	15

Based on Table 1, the highest number of samples of *C. lingua* was obtained from Cilacap, namely 750 samples. Meanwhile, the largest maximum length and weight were found in

Bojong Salawe and Cikidang, with a maximum length of 47 cm and a maximum weight of 734 g.

Length frequency distribution. Calculating the frequency of fish length aims to determine the range with the highest number of longest, shortest and largest fish specimens (the distribution of the sample being measured). The observation results on the length distribution of the captured *C. lingua* can be seen in Figure 3 below.

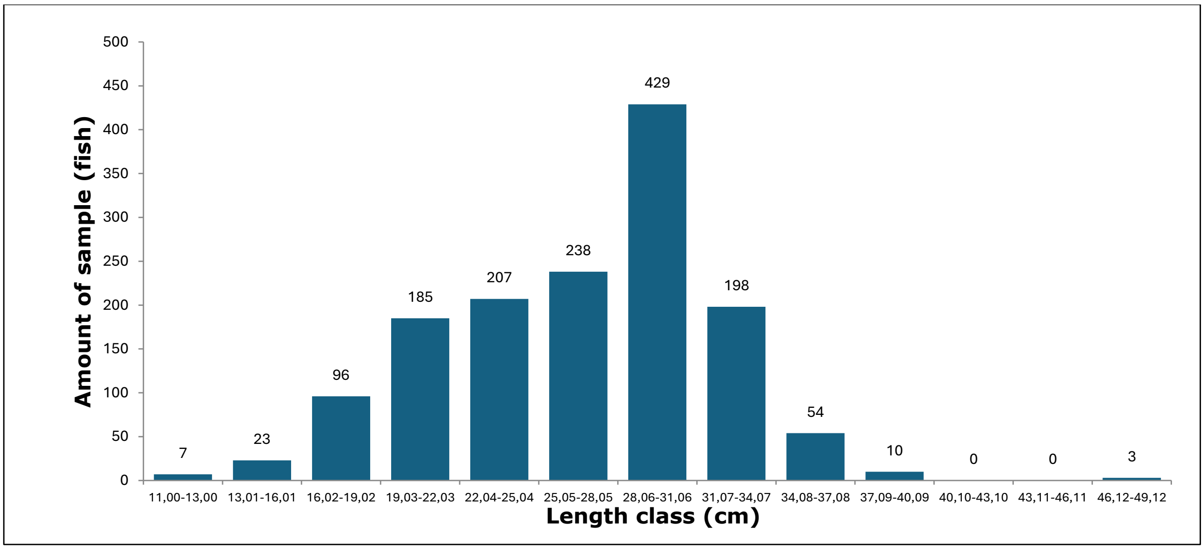

Figure 3. Frequency of class length of *Cynoglossus lingua.*

Figure 3 shows the class length frequency of *C. lingua* in the waters of Cilacap and Pangandaran. 1,450 fish of size *C. lingua*, ranging in length from 11.00 to 49.12 cm, were collected for the study. In total, 145 individuals could be studied. The distribution of length frequency measures varies based on gender. The size of female fish ranged from 11–47 cm, while the size of male fish ranged from 11.5 to 40 cm. The most caught fish ranged from 28.06 to 31.06 cm with a total of 429 fish. This pattern is similar to the study of Sulistiono et al (2011) in Ujung Pangkah Waters, East Java, Indonesia. In their research, the total length *C. lingua* ranged from 6.5 to 32.3 cm. The length of female fish ranged from 6.5 to 32.5 cm, while male fish ranged from 6.5 to 15.1 cm. This difference in size is caused by differences of the aquatic environmental conditions at the sampling locations. If fish of the same species live in different waters, they will experience different growth (Tarigan et al 2017).

Length weight relationship. Fish length-weight analysis is very important to determine the biological condition of fish and fish stocks. In addition, fish length-weight analysis is carried out as a biological indicator of the condition of the aquatic ecosystem (Muttaqin et al 2016; Setiyowati 2016; Zuliani et al 2016; Kumayanjati et al 2019). Table 2 shows the relationship between length and weight of *C. lingua* obtained during the research in Cilacap and Pangandaran waters.

Table 2

Length weight relationship of *Cynoglossus lingua*

Number of samples	R^2	t_{count}	t_{table}	$W = aL^b$	*Growth characteristic*
1,450	0.9250	55.2885	1.961601	$W=101.7691L^{0.0012}$	Allometric negative

The results of the regression analysis, based on the obtained equation ($W = 101.7691\ L^{-0.0012}$), resulted in a coefficient of determination (R^2) is 0.9250, which means that length heavily influences the body weight of the fish. The regression hypothesis test (t_{test})

determined a t_{count} of 55.2885 and a t_{table} equal to 1.9616 ($t_{count}>t_{table}$). The b value was determined: 0.0012 (b<3), indicating that fish growth has a negative allometric pattern (Wu et al 2010).

The relationship between the length and weight of the fish obtained was determined using the t_{test} at a 95% confidence interval α = 0.05 (Lestari & Machrizal 2022). The conclusions drawn from the value $t_{count}>t_{table}$ shows a non-trivial relationship and the b value indicates a negative allometric growth pattern. Figure 4 shows an analysis of the relationship between length and weight *C. lingua* who were captured and landed at 3 points in Cilacap and Pangandaran.

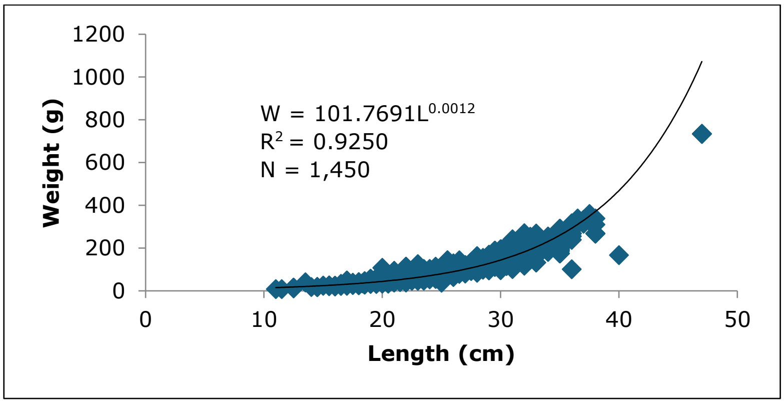

Figure 4. Relationship between length and weight of *Cynoglossus lingua.*

The analysis presented in Figure 4 shows that *C. lingua* has a length of 11 to 47 cm, and a weight of 8 to 734 g. Based on the t-test (at the 95% confidence interval) and on the b value, a negative allometric growth pattern was obtained, similarly to Nurhayati & Prianto (2017), on *C. lingua* from Ujung Pangkah Waters, East Java, where the obtained b values (<3) indicated a growth pattern allometrically negative. The b value is influenced by the behavior of the fish; for example, fish that swim actively show lower b values when compared to fish that swim passively. This is related to the allocation of energy expended for movement and growth (Muttaqin et al 2016). Availability of food, level of gonad maturity, and variations in body size of sample fish can also be causes of differences in b values (Hasibuan et al 2018).

Sex ratio. The optimal ratio of the number of male and female fish in a population for maintaining the continuity of a species is 1:1 (50% male and 50% female) (Hamjan et al 2020). The sex ratio of male and female fish can be analyzed using the Chi-Square test (Rachmawati & Hartati 2017). From observations of 1,450 *C. lingua* individuals, only 145 (10%) could be morphologically identified as sexed. Of these, 50 (34%) were identified as male and 95 (66%) as female, resulting in a male to female sex ratio of 34%:66% (Figure 5).

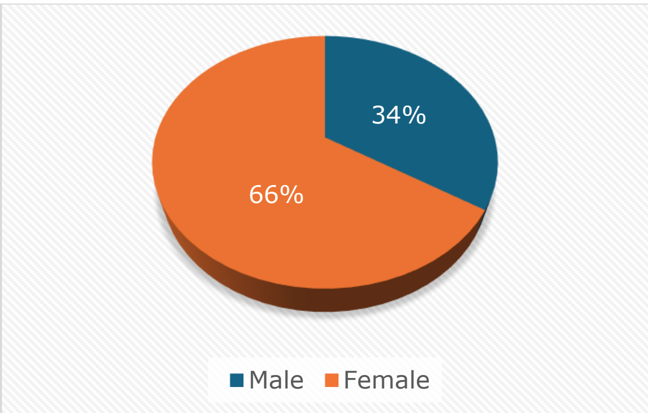

Figure 5. Percentage of sex ratio of *Cynoglossus lingua.*

To determine whether *C. lingua* is in an ideal condition to maintain its sustainability, based on the assumption that one male *C. lingua* will spawn one female *C. lingua*, it is necessary to test the sex ratio value of 1:0.90 whether it is 1:1. This test uses the chi square test with degrees of freedom (db)=1 and a confidence level of 95%. The determined chi-square (x^2) value obtained is 13.96, which is greater than the table chi-square (x^2) value of 3.84, which means $x^2_{count}>x^2_{table}$. This condition indicates that H_0 rejected, H_1 accepted which means that the resulted ratio between male and female fish, which is 1:1.9 indicates a significant difference between female and male numbers of *C. lingua.* The difference in the number of male and female *C. lingua* is thought to be due to differences in schooling behavior between male and female fish. An imbalance in the number of male and female fish in a population will have an impact on decreasing the fish population in a body of water. This can occur due to excess fishing or uncontrolled fishing activities (overfishing). Changes in the sex ratio can be caused by high fishing intensity, environmental factors and fishing gear selectivity (Wardhani et al 2024).

Gonad maturity level (GML). GML on *C. lingua* information is needed to determine the ratio of fish that have and have not matured gonads, among the number of fish sampled. Figure 6 below shows a diagram of the percentage of GML for male and female fish.

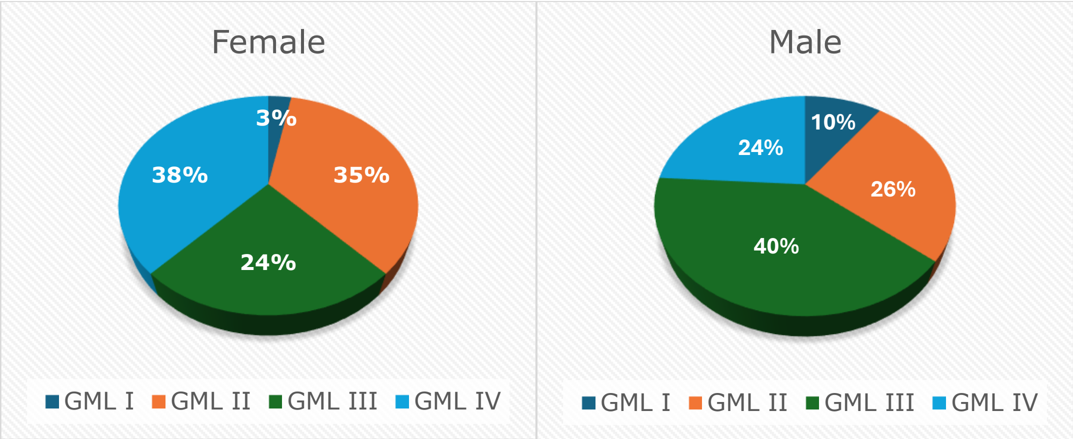

Figure 6. GML percentage of *Cynoglossus lingua.*

As shown in Figure 6, among the 95 studied females, 3 had a GML I (3%), 33 a GML II (35%), 23 a GML III (24%), and 36 a GML IV (38%). Overall, most of the caught females had a GML IV (mature gonads). Among the 50 males studied, 5 had a GML I (10%), 13 a GML II (26%), 20 a GML III (40%), and 12 a GML IV (24%). Thus, it can be concluded that overall, the caught male fish were dominated by male fish with GML III or already mature gonads. From the perspective of the GML of the catch, the chance of occurrence of recruitment overfishing is also very big. Recruitment overfishing occurs when fishing activities catch a lot of fish ready to spawn (spawning stock). From the results of observations during the research, it can be seen that *C. lingua* is dominated by fish with mature gonads (GML III and IV), which indicates that the fish have entered the spawning season.

Length at first capture (LC) and length at first maturity (Lm). Calculation of the average Lc size was carried out using the cumulative frequency in each Lc class. The Lc was analyzed by the cumulative percentage of fish caught. The average Lc is presented in Table 3.

Table 3

Lc and Lm analysis results

Sample	*ni*	*Fi*	*Ri*	$Pi = \frac{ri}{ni}$	*X=xi²-xi¹*	*qi = 1-pi*	*Pi*qi/ni⁻¹*	*Lc*	*Lm*
C. lingua	145	54	91	5.3938	1.1703	4.6062	0.8557	33.73	12.86

Lm values of *C. lingua* varied between 12.86 and Lc 33.73 cm. Based on the calculation results in the table above, the length class (LC) of exploited fish populations exceeds the length at first gonadal maturity (LM), indicating that *C. lingua* reproduced at least once before being caught. This reflects a biologically and ecologically sustainable exploitation pattern. It also indicates that current fishing practices allow for adequate recruitment and maintenance of stock biomass, in accordance with established fisheries management principles. This means that the fish are suitable for catching: they could spawn before being caught, thus increasing the population in the waters. The size and maturity of gonads for fish species will vary, due to differences in temperature, food, sex and water conditions. A research conducted by Hasibuan et al (2018) on *C. lingua* in Palabuhanratu bay found an Lm of 14.4 cm and an Lc of 18.6 cm.

Trends in fishing productivity and CPUE. The fishing gear productivity is the catches quantity obtained from the fishing efforts (Nelwan et al 2016). Catch, effort and CPUE are used as indicators of sustainable fisheries management. The general pattern of a fishery experiencing overfishing is a rise of the total effort, followed by a rise in catch volumes, triggering a decrease in CPUE (Susanto et al 2015).

The flat CPUE trend is an illustration that the level of exploitation of fish resources is approaching the effort saturation, while decreasing CPUE is an indication that the excessive level of exploitation of the fish resources leads to overfishing (Anas et al 2016). Differences in *C. lingua* catch per unit of fishing effort, in the Cilacap and Pangandaran waters, are presented in Figure 7 and Figure 8.

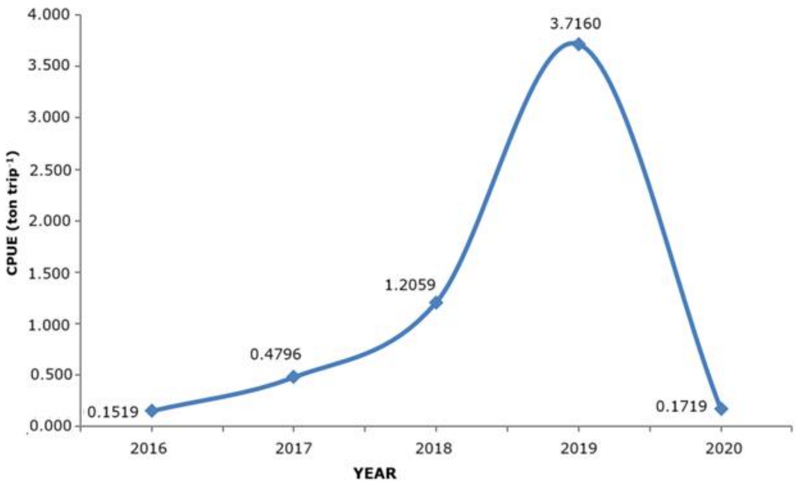

Figure 7. Pangandaran CPUE graph.

The annual production of *C. lingua* from 2016 to 2020, Pangandaran waters experienced fluctuations (Figure 7) (DKPKP 2020). The highest production, recorded in 2019, was 3.7160 tons year^{-1} with a total effort of 518 ships and the lowest production occurred in 2020, with 0.1719 kg year^{-1}. The highest increase in the fishing effort occurred in 2020, with a total effort of 643 units, resulting in a drastic decline in catches. Each additional effort of 1 trip caused the CPUE value to decrease by 3.1219 tons trip^{-1} and a reduction of the effort by 1 trip increased the CPUE value by 3.1219 tons trip^{-1}.

The production and effort of *C. lingua* from 2016 to 2020 in Cilacap experienced fluctuations (Figure 8) (DKP 2020). The highest production in 2016 was 0.0241 tons trip^{-1} with a total effort of 5,834 ship units and the lowest production was in 2018 of 0.0073 tons trip^{-1} with a total effort of 8,335 units. Figure 8 shows an unstable production: increasing the fishing effort reduced the catches.

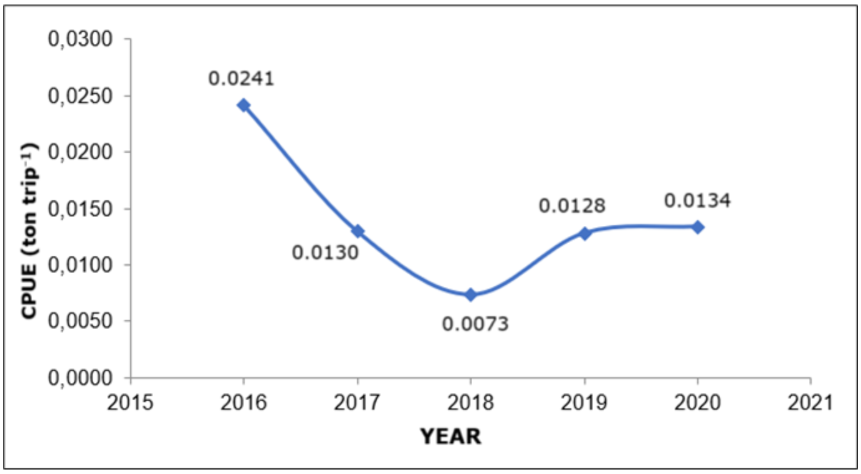

Figure 8. Cilacap CPUE graph.

Management efforts of C. lingua. Reproductive biology knowledge supports the fish management. The Lm estimation for the sampled *C. lingua* is one way to determine the population development in a water body. The length values found during the research were 11 to 47 cm, with the average Lm (12.86 cm), smaller than the average Lc (33.73 cm). It can be concluded that the fish were caught after spawning. Fisheries management is not related to the biological aspect, but it concerns also three other aspects, namely economic, social and environmental. The CPUE in Cilacap and Pangandaran waters during (2019 to 2020) experienced fluctuations. An increase in effort could endanger the *C. lingua* stock sustainability in the region.

Conclusions. In the 1,450 studied samples of *C. lingua*, a fish growth negative allometric was observed. The sampled *C. lingua* were dominated by GML II and GML III. Their Lc>Lm indicate that the captured fish had already spawned. CPUE trends in Cilacap and Pangandaran have fluctuated. The level of utilization of *C. lingua* in Pangandaran Waters is not yet optimal, since additional fishing efforts are still possible. This is different from Cilacap Waters which can utilize *C. lingua* although it has not reached the optimum level. LC >LM indicates that C. lingua reproduced before capture. This also indicates that current fishing practices allow for adequate recruitment and maintenance of stock biomass.

Acknowledgements. The authors would like to thank to the head of the Faculty of Waters Resources Management, Jakarta Technical University of Fisheries, for their support during the current research.

Conflict of interest. The authors declare that there is no conflict of interest.

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Received: 01 March 2025. Accepted: 12 September 2025. Published online: 04 October 2025.

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How to cite this article:
Hermawan M., Nugraha E., Yusrizal, Dewi P., Utami F. P., Maulita M., Suharti R., Sayuri M., Danapraja S., 2025 Biological aspects of long tongue sole, *Cynoglossus lingua*, in the South Sea of West Java, Indonesia. AACL Bioflux 18(5):2212-2224.