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Biological aspects of squid (*Loligo edulis*) in the waters of Eastern North Sumatra, Indonesia

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ABSTRACT

Squid is one of the non-fish resources that have economic value and is a target species in demersal fisheries activities with squid fishing gear and stick-held deep net. This research aims to determine the biological aspects of squid (*Loligo edulis*) such as length frequency distribution, length-weight relationship, sex ratio, gonadal maturity level, gonadal maturity index, size at first caught, and size at first maturity of the gonads. The method used in this research was a descriptive survey. The sample collection method used systematic random sampling and purposive sampling techniques. This observation was carried out on March 7 to July 30, 2022, at the Belawan Ocean Fishing Port and Tanjung Balai Port. The results showed that the average length distribution of squid was 17.73 cm. The relationship between the length and weight of squid is negative allometric. The sex ratio is 1:1.05. The negative allometric growth pattern is dominated by Gonadal Maturity Level (GML) I and GML II. The highest GML value for male squid was 2.06% at GML III, and the highest GML value for female squid was 1.92% at GML III. The average size of the caught squid length (Lc) is 10.42 cm. The size of the first gonad maturity (Lc) was 13.32 cm.

Introduction

Geographically, the waters of the Malacca Strait are part of fisheries management areas (WPP) 571 (Arsana, 2014) The northeastern area is directly adjacent to Economic Zones (EEZ) waters of Malaysia, Thailand, and Singapore, the southwest is administratively bordered by the three provinces of the east coast of Sumatra namely the southwest is administratively bordered by the three provinces of the east coast of Sumatera (Aceh, North Sumatera, and Riau) to the northwest to the waters of the Andaman Ocean and the southeast to the waters of the southern Natuna Ocean. This region, based on the estimation of fish resource potential (FRP), has 9 (nine) FRP groups, namely large pelagic fish, small pelagic fish, demersal, penaeid shrimp, consumable crayfish, lobsters, crabs, and squid (Faizah and Sadiyah, 2019).

This region stretches along the east coast of North Sumatra. The east coast of North Sumatra has a 545 km coast and consists of 7 regencies or cities, namely Langkat Regency, Medan City, Tanjung Balai City, Asahan Regency, Labuhan Batu Regency, Deli Serdang Regency, and Serdang Bedagai Regency. The East Coast of North Sumatra is a busy shipping lane and one of the areas for fishing activities, especially in Belawan Waters. Belawan is a magnet for North Sumatra's fishing activities (Tambunan *et al.*, 2010).

The fishery resources in the east coastal area of North Sumatra consist of fish and non-fish resources. One of the non-fish resources is squid. Squids are invertebrates that are classified as pelagic but are sometimes classified as demersal due to their frequent bottom presence. They are members of the mollusk phylum's cephalopod class (Faradizza *et al.*, 2019; Surachmat, 2018). Squid fisheries are now one of the potential non-fish resources that have important economic value and are widespread in Indonesian waters (Nababan *et al.*, 2017). The tools

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used are squid nets, stick-held deep nets, squid fishing rods, and by-catches from ring trawls and fish trawls (Ilhamdi and Yahya, 2017).

The increasing intensity of fishing and the number of fishing fleets as well as the modernization of fishing gear can lead to overfishing. In addition, the high rate of degradation of spawning habitats, the enlargement of squid in coastal areas due to pollution, environmentally unfriendly fishing, sedimentation, and land conversion as a result of development can result in a reduction in squid populations (Baskoro *et al.*, 2017).

Squid (*Loligo* spp.) caught in the waters of Eastern Sumatra is mostly landed at Belawan Ocean Fishing Port (PPS Belawan) and Tanjung Balai Asahan Port. Data on squid catches and fishing efforts in the Eastern Waters of Sumatra landed in Belawan Ocean Fishing Port (PPS Belawan) from 2016 to 2020 on the ecological dimension, technological dimension and social dimension are included in the category of less sustainable (Chairunnisa, 2022).

The need to maintain squid resources (*Loligo* spp.) is to maintain the potential of squid to be optimally utilized so that there is no overfishing. Therefore, it is necessary to study the basic information on biological aspects, aspects of capture fisheries, and management efforts to support efforts to manage squid resources (*Loligo* spp.) sustainably and the creation of sustainable and environmentally friendly fishing.

Based on the explanation above, it is necessary to conduct research that aims to analyze various aspects of squid biology and reproduction, including length frequency distribution, length-weight relationship, sex ratio, gonadal maturity level (GML), gonadal maturity index (GMI), the length of the first maturity, and the length of first captured.

Materials and Methods

Location and time

This research was carried out from March to May 2022 which months are known as transitional seasons (Ariyanto *et al.*, 2021) and was located at two squid landing locations in the eastern region of North Sumatra which include:

1. Belawan Ocean Fishing Port, Bagan Deli Village, Medan District Belawan City, North Sumatra Province
2. Tanjung Balai Asahan Port, Bagan Asahan Village, Tanjung Balai Teluk Nibung District, North Sumatra Province.

Sampling activities are carried out every day, where 1.5 months are located in Belawan Ocean Fishing Port and the remaining 1.5 months are located in Tanjung Balai Asahan Port.

Data collection

The tools and materials used during the observation are shown in Table 1.

Table 1. Tools and materials.

No.	Tools	Specifications	Function
1.	Stationery	-	To log data
2.	Iron Ruler	1 cm	To measure the length of the squid
3.	Plain Paper	-	As a squid base
4.	Digital Scales	1 gram	Measuring squid weight
5.	Tissue	-	To clean the tool
6.	Mobile Camera	48 MP	For documentation of practical activities
7.	Laptop	-	To process data
8.	Squid	-	Samples used
9.	Field Form	-	As a medium for recording data

The data collection method during this research is a direct survey method, namely by looking at and making observations in the field of squid samples that are the target of observations. The data retrieved are primary data and secondary data.

Primary data are obtained from the field such as measurements of length and weight, gender, gonadal maturity level, and others. As well as conducting direct interviews with fishermen or respondents using the questionnaires that have been provided (Mustaqim, 2016; Daud *et al.*, 2020).

Squid sampling (*L. edulis*) used a random sampling method. Dissected sampling was taken using the purposive sampling method

Data analysis

Squid mantle length frequency distribution

The length frequency distribution is obtained by determining the class interval, middle grade of the class, and the predetermined length frequency distribution in class intervals then calculated using descriptive statistics then presented in the form of graphs (Selvia *et al.*, 2019).

Relationship between length and weight

Measurements of total length and weight were performed to compare eating habits based on groups of class length measures (Ismail *et al.*, 2013). According to Perangin-angin *et al.* (2015) the steps to determine the structure of the catch population using data on the length of the mantle are as follows:

1. Specifies the class range (J), with the formula: Range = largest data – narrowed data l
2. Specifies the number of interval classes (C), with the formula: C = 1 + 3.3 log n (n = number of samples)

3. Determining the length of the class interval (C), using the formula: C = Range/Number of Interval Classes
4. Enter the length of each specimen instance in a predetermined class.

The relationship between length and weight uses a linear allometric model. This model is used to calculate parameters a and b through measurements of length and weight (Brinkman, 1993):

$$W = a\ L^b$$

Information:
W: Individual weights of squid (g)
L: Mantle length (cm)
a. Intercept (intersection of the curve of the relationship of the length of the weight with the y-axis)
b. Slope

Linear or straight-line equations are obtained from the following equations:

$$L_n\ W(i)=L_nq+bL_n(i)$$

Parameters a and b were obtained from Regression Analysis with Ln W as 'y' and Log (i) as 'x', so the regression equation is obtained as follows: $y = a + bx(i)$ (Muhsoni, 2019). The coefficients of determination and correlation can also be determined through equations.

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

1. b < 3: Length gain is faster than weight gain (negative allometry)
2. b = 3: Length gain balanced with weight gain (isometric)
3. b > 3: Weight gain is faster than length gain (positive allometry) (Perangin-angin *et al.*, 2015)

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

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

Information:
t_s = Bailey's t-test,
b = the slope of the linear regression
Sb = standard error of the b coefficients

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

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

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

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

Length of first captured (Lc)

Length of first captured according to (Sparre-Venema, 1998):

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

The Lc value is obtained by plotting the percentage of the cumulative frequency of squid caught by its standard length size, where the cut-off point between the curves of 50% cumulative frequency is long when 50% of squid are caught (Tirtadanu and Ernawati, 2016) the value of Lc can be calculated through the formula:

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

Information:
a: Intercept
b: Slope

***Length of first maturity* (*Lm*)**

The size length of the first maturity is a variable of the reproductive strategy in squid, besides the sex ratio and spawning periods and types (Barokah *et al.*, 2016). Calculation of the length of the squid length of the first maturity (Lm) using the Spearman-Karber equation method developed by Udupa (Abubakar *et al.*, 2019):

$$m=x_k+\frac{d}{2}-\left(d\sum P_i\right)$$

Information:
m: Logarithms of a length class at the first maturity
d: The difference in the logarithm of the addition of the mid-length value
k: Number of length classes
x_k: Logarithm of the mid-value of the length of the fish that has matured gonads (Pi=1)

Sex ratio

According to (Fisher, 1930) the ratio of male to female individuals is estimated at 1:1 naturally in water with a normal spreading population. The equation used to calculate the sex ratio is as follows:

$$\text{Sex Ratio}=\frac{n\ J}{n\ B}$$

Information:
n J: The number of male squids (individuals)
n B: The number of female squids (individuals)

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To find out whether there is a real difference between the comparison of male and female individuals, it is carried out through testing and testing 'X²' (chi-square) with a formula according to (Legendre and Legendre, 2003; Mchugh, 2013):

$$\Sigma X_{i-j}^2 = \frac{(O-E)^2}{E}$$

Information:
O = Observed (the actual count of cases in each cell of the table)
E = Expected value (calculated below)
χ2 = The cell Chi-square value
∑χ2 = Formula instruction to sum all the cell Chi square values
χ2i-j = i-j is the correct notation to represent all the cells, from the first cell (i) to the last cell (j)

The value of χ2 obtained from this calculation compared with the value of χ2 in the table with a confidence level of 95% and a free degree (FD) = 1 (one) with the hypothesis:
H_0: There is no noticeable difference between the number of male and female squid
H_1: There is a noticeable difference between the number of male and female squid
If,
X^2 calculate < χ2 table = H_0 Accepted, H_1 rejected
X^2 calculate > χ2 table = H_0, Rejected, H_1 accepted.

***Gonadal maturity level* (*GML*)**

The basis used to determine GML morphologically is the shape, length, color, and development of the gonadal content. Classification of the gonadal maturity level of squid is suggested (Lipiński and Underhill, 1995) in Table 2.

Table 2. The microscopic sexual maturity scale applied for *Loligo edulis*.

Maturity Stage	Histological Examination	
	Males	Females
I immature	The first spermatogonia and first primary spermatocytes developed anywhere in the gonad.	The first oogonia developed anywhere in the gonad.
II developing	Tubules with primary spermatocytes inside are clearly defined.	Follicle cells surround the oocyte anywhere in the gonad.
III maturing/ripening,	First spermatids develop anywhere in the gonad.	First invagination of the follicular epithelium.
IV mature/ripe/gravid	First spermatozoa are formed anywhere in the gonad.	Yolk finishes displacing follicular folds in the gonad
V spent	None	First mature oocytes are found anywhere in the gonad.

***Gonadal maturity index* (*GMI*)**

Determining the GMI value of fish can be used the formula below (James *et al.*, 2010):

$$GMI = \frac{GW}{BW} \times 100\%$$

Information:
GW: Gonadal Weight (grams)
BW: Squid Body Weight (grams)
GMI: Gonadal Maturity Index

Results

Biological aspects of squid

The morphological features of the squid obtained are elongated cylindrical shape and the back is tapered with a pair of triangular-shaped fins. Squids found have soft bodies, a pair of eyes next to the head, and five pairs of arms, where one pair of arms is longer than the other called tentacles. The squid found at the research location is shown in Figure 1.

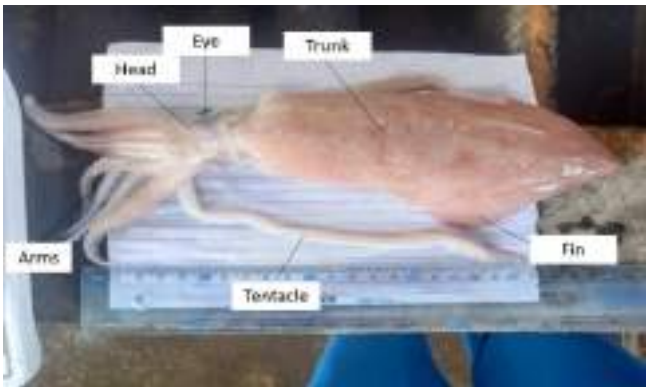

Figure 1. Squid (*Loligo edulis*) found at the research location.

Squid mantle length frequency distribution

Squid sampling (*L. edulis*) obtained during research was taken from 2 landing locations located in North Sumatra Province. The results of observations on the distribution of mantle lengths (*L. edulis*) for intervals caught and landed at the Ocean Fishing Port of Belawan and Tanjung Balai Asahan Port are presented in Figure 2.

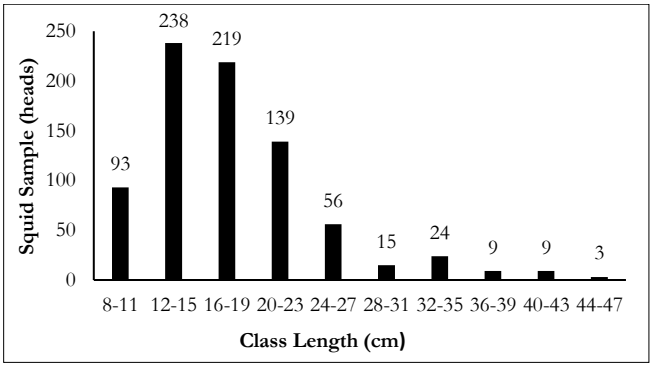

Figure 2. Squid length frequency distribution (*Loligo edulis*)

The maximum and minimum values of squid mantle length are presented in Table 3.

Table 3. Squid frequency distribution (*Loligo edulis*).

Location	Number of Samples	Mantle Length		
		Min (cm)	Max (cm)	Average (cm)
Belawan Ocean Fishing Port	455	8	46	18.25
Tanjung Balai Asahan Port	350	8	41	17.05

Weight length relationship

The relationship between the length and weight of the squid is presented in Table 4.

Table 4. The weight length relationship of squid (*Loligo edulis*) captured.

Squid Samples	$W = aL^b$	R^2	R	n	T-test	Growth characteristic
Squid (*Loligo edulis*)	$W = 0.5640L^{1.9797}$	0,8935	0,9452	805	$T_{value} > T_{table}$ 42,30 > 1,96	Negative allometric

Sex ratio

The squids that were taken from 2 locations as samples were 80 squids. The samples were dissected to see the characteristics of the gonads which consisted of 42 female squids (53%) and 38 male squids (47%) with a sex ratio = 1.05:1.

To find out whether the squid is in ideal conditions to maintain its sustainability, it is necessary to test the sex ratio value. This test uses a chi-square test with a free degree (FD) 1 and a confidence level of 95 % presented in Table 5.

Table 5. Chi-square test of squid sex ratio at two locations.

Sample	f_0	f_h	$f_0 - f_h$	$(f_0 - f_h)^2$	$(fo-fh)^{FH}fh$	$\sum (f_0 - f_h)^2/f_h$	χ^2_{table}
Male	38	40	-2	4	0,1	0,2	3,84
Female	42	40	2	4	0,1		
Total	80				0,2		

Gonadal maturity level (GML)

A sampling of the overall maturity level of the gonads dissected was 80 samples from 805 squid samples measured and weighed obtained from fishermen in the eastern waters of North Sumatra. From the level of gonadal maturity of 80 dissected sample squid caught in the eastern waters of North Sumatra, a level of gonadal maturity varies from GML I to GML IV. The followings are the male GML of squid caught in the Eastern Waters of the Island of Sumatra shown in Table 6.

Gonadal maturity index (GMI)

Based on the results of the observation that the range values of the Gonadal Maturity Index (GMI) of male and female squids at the research location showed varying amounts. The gonadal maturity index chart is presented in Figures 3 and 4.

Table 6. The gonadal maturity level of squid.

Gender	GML										Σ
	1		2		3		4		5		
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	
Male (squid)	16	42	7	18.5	7	18.5	8	21	-	-	38
Female (squid)	6	14	15	36	12	29	9	21	-	-	42
Male and Female (squid)	22	27	22	28	19	24	17	21	-	-	80

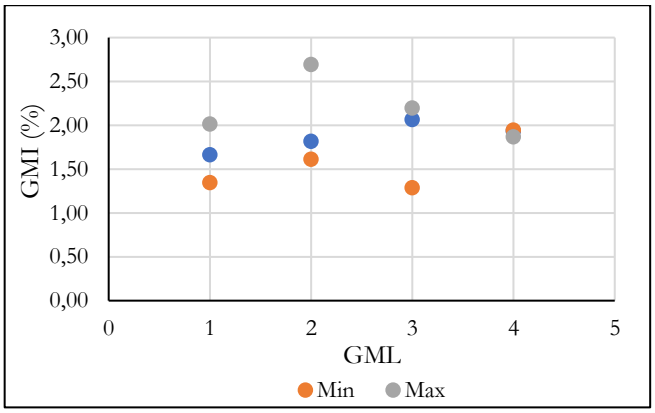

Figure 3. The gonadal maturity index (GMI) of male squid gonads caught in the eastern waters of North Sumatra.

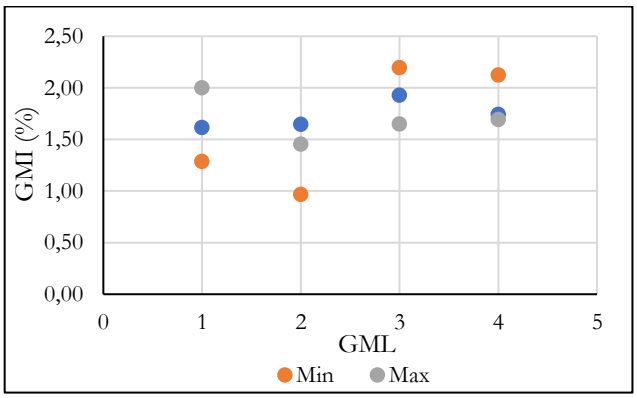

Figure 4. The gonadal maturity index (GMI) of female squid caught in the eastern waters of North Sumatra.

Length at first capture (Lc)

The following is a graph of the size first caught on a squid (*L. edulis*) caught in the waters east of the island of Sumatra presented in Figure 5.

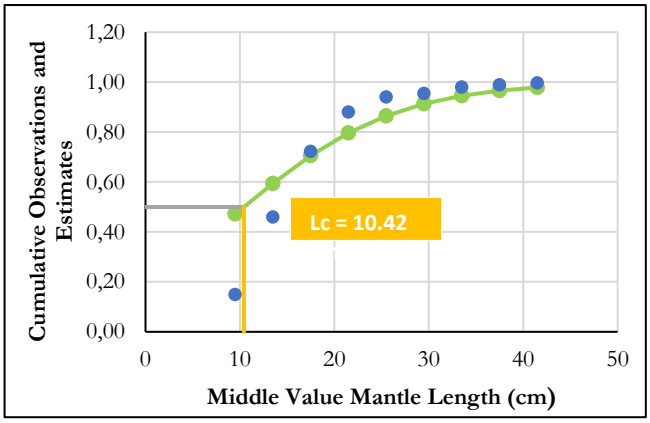

Figure 5. The length of the first capture of squid at two study locations.

Length at first maturity (Lm)

Statistical calculations using a confidence level of 95% to estimate squid (*L. edulis*) that have entered the maturity category of gonads are presented in Table 7.

Table 7. Length of squid mantle when first maturity gonads (Lm) obtained.

Gender	95% trust	Lc (cm)	Lm (cm)
Combined	12.79 – 13.91 cm	10.42 cm	13.32 cm

The size of the first maturity squid gonads is presented in the diagram in Figure 6.

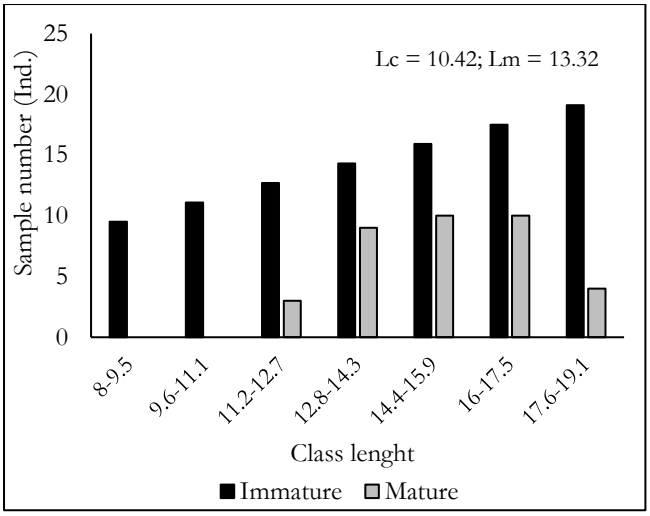

Figure 6. The size of the first maturity squid gonads caught in the waters east of North Sumatra.

Discussion

Figure 2 shows the frequency of squid class length landed at 2 squid landing locations in North Sumatra Province totaling 805 squids with a mantle length (cm) ranging from 8–47 cm with an average of 17.73 cm, and a weight range between 26–728 grams with an average of 188.65 grams. The most caught squids ranged from 12–15 cm mantle length class interval of 238, while the fewest caught squids ranged from 3 mantle length class interval.

The average length of this mantle is much bigger when compared to the same type of squid caught in the waters of Belanakan Subang from November 2005 –June 2006. The average length of the *L. edulis* mantle caught in Belanakan Subanga at 16.5 cm (Puspasari and Triharyuni, 2013). The difference in size between squid landed at the Ocean fishing port of Belawan and at Tanjung Balai Asahan Port in 2022 and squid landed in Belanakan Subang in 2005–2006 can be caused by several actors, including the differentiation of fishing gear.

Squid landed at the ocean fishing port of Belawan and Tanjung Balai Asahan Port is the catch of squid fishing rods and stick-held deep net (Reza *et al.*, 2019) which operates in areas about 12 miles from the shore, with only a small operating time. Meanwhile, the squid that landed in Belanakan in 2005 was caught by purse seine and danish seine operating on the high seas with the help of lights (Puspasari and Triharyuni, 2013). The lamps used have a power of 750-1.500 watts and amount to 24-90 pieces (Triharyuni *et al.*, 2012).

According to Tasywiruddin (1999), small-sized squids are more commonly caught in waters farther from the coast and small-sized squids are more phototaxis when compared to large-sized squids so that when caught using the help of light, small squids will be caught more. Thus the difference in size that occurred in squid landed in Belanakan in 2005–2006 with squid landed at the ocean fishing port of Belawan and Tanjung Balai Asahan Port in line with the results of his research.

The maximum and minimum values of squid mantle length being presented in Table 3 can be explained as follows: Squid samples (*L. edulis*) measured in two locations, namely the Belawan Ocean Fishing Port, totaled 45 squids consisting of 25 female squids and 20 male squids, while in Tanjung Balai Asahan Port 35 squids were consisting of 17 female squids and 18 male squids. The average difference in length obtained in the two locations is in Belawan Ocean Fishing Port of 18.25 cm with a length class interval range of 8-46 cm and Tanjung Balai Asahan Port of 17.05 cm with a length class interval range of 8-41 cm. The difference is not so significant from the size of the squid mantle length in the two areas because the conditions in both environments and the fishing gear used are almost the same.

The relationship between the length and weight of squid presented in Table 4 shows that the

calculated T value is greater than the T-table which can be interpreted as rejecting the null hypothesis (H_0) by showing a negative allometric growth pattern. The equation of the relationship between squid weight lengths in two research locations caught in the eastern waters of North Sumatra is $W = 0.5640L^{1.9797}$ with b = 1.9797 where the value of b < 3 (negative allometric) which means that the increase in squid length is greater than the increase in squid weight. The correlation value of the squid weight length relationship is $R^2 = 0.8935$ with a value close to 1 which means that the weight length relationship is very closely related (Budiwanto, 2017).

The sex ratio of fish can be used as one of the parameters to give an idea of the abundance (Kudale and Rathod, 2016) and balance of fish in the water (Wujdi and Wudianto, 2013). The results of the squid's sex ratio shown in Figure 4 explained that there are 42 female squids (53%) and 38 male squid (47%) by comparison of sex ratio = 1.05:1. The above conditions according to Limbong and Rahmani (2022) illustrate that the condition of the eastern waters of North Sumatra will quickly recover from fishing activities. Tampubolon *et al.* (2019) furthermore revealed that the ratio of squid populations as shown in Figure 4 in water where the number of male and female fish is balanced, or more female fish will recover faster than a population dominated by male fish.

Based on Table 5, X^2calculation < X^2 table, then H_o was accepted, which means that there is no noticeable difference between the number of male squids and female squids caught and obtained. The findings in the field show that the ratio of females and males is balanced according to Ayorbaba *et al.* (2019).

The maturity level of the male squid gonads obtained during the study was dominated by GML I and only a small part of the mature gonads (GML III and IV) were 15 individuals. While the maturity level of the female squid gonads obtained during the study was dominated by GML II and III only a small part of the mature gonads (GML IV) were 9 individuals, see (Figure 6). There are differences in the phase of maturity of the gonads between males and females. It means that the squid is in the gonadal maturity phase every month, it is suspected that the squid spawns throughout the year, while the peak takes place in March and April.

Figures 3 and 4 above showed that the gonadal maturity index (GMI) of male and female squid shows variations. The highest male squid GMI value was found in GMI III at 2.06% and the lowest at 1.66% in GMI I, and the highest female squid GMI value was at GMI III at 1.92% and the lowest at 1.61% in GMI I.

The most dominant GMI was GMI III, both male and female. Where, the GMI value of male squid is greater than the GMI value of female squid (2.06% > 1.92%), which means that when mature, the male squid gonads tend to have a greater weight than female squid because the more mature the gonads had the squid's body will be heavier and will decrease during the reproductive process gradually. The results of the research cnducted at the research site are the same as the result of the study by Perangin-angin *et al.* (2015).

The gonadal maturity index (GMI) needs to be done because it can know changes in the gonads quantitatively (Satyani, 2017). GMI growth is directly proportional to GML, meaning that the higher the GML value, the higher the GMI value (Muharam *et al.*, 2020). When spawning will occur, the GMI will increase in value and reach the maximum limit and will decrease after finishing working (Ridho and Patriono, 2016). The weight of the gonads was weighed using analytical scales, then the weight of the gonads was compared with the weight of the body and the result was obtained in the form of a percent (%) (Pane and Hasanah, 2019).

The results of the analysis presented in chart 9 above show that the size of the length of the first captured (Lc) squid as a whole, which amounted to 350 sample squid caught using stick-held deep nets (squid net) fishing gear in the waters east of North Sumatra, was 10.42 cm. interval size range of the mantle length is 8 – 47 cm with a mode in the class of 13.5 cm. Compared to the results of research conducted (Pertiwi *et al.*, 2022), Lc value at the study site (10.42) is smaller than Lc at Tasik Agung Rembang Beach Fishing Port (12.53). This condition shows that there is a higher catch pressure at the study site than at the Tasik Agung Rembang Beach Fishing Port. Efforts that need to be made to the above conditions are to limit arrest attempts by issuing regulations related to this matter. While the remaining 455 squid samples were captured using fishing gear which was not included in the Lc calculation because the data used to calculate Lc only used net fishing gear.

It is explained in Table 7 above that the results of the calculation of the analysis of the size of the first maturity squid gonads dissected were 13.32 cm. This size range shows that squid has entered the category of mature gonads (range length) between 12.79 to 13.91 cm.

Based on the calculation results in Table 6, the value of Lc < Lm or it can be interpreted that the squid is not yet suitable for catching and could grow and spawn before being caught. They can also still increase the population of water. In other words, the squid caught has not had time to spawn first. Research conducted by (Pertiwi *et al.*, 2022) at the Tasik Agung Rembang Beach Fishing Port for squid showed an Lm value of (16.50 cm) where this result was greater than the Lm from the place of study location (13.32). This condition shows that the habitat in the Tasik Agung Rembang Beach Fishing Port area is better than the location where the research was carried out.

The comparison in the two places shows that the Lc obtained is smaller than the Lm where which shows that the squid is not yet suitable for catching and could grow and spawn before being caught. They can also still increase the population of water. In other words, the squid caught has not had time to spawn first.

Conclusion

The most captured squid ranges in the interval of the mantle length class of 12 – 15 cm, while the least caught squid ranges in the interval of the mantle length class 44 – 47. Squids grow allometrically negatively, with a balanced sex ratio of 1:1.05. The maturity level of gonads in male squid shows that GML I is the most dominant (42%), while for females GML II is the most dominant (35.71%). The differences in the phase of maturity of the gonads between males and females mean that the squid is in the gonadal maturity phase every month. It is suspected that the squid spawns throughout the year. The Lc value is smaller than the Lm value (12.45 cm < 13.34cm), which indicates that the caught squid has not had time to spawn first.

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Biological Aspects of Squid (*Loligo edulis*) in The Waters of Eastern North Sumatra

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ABSTRACT

Squid is one of the non-fish resources that have economic value and is a target species in demersal fisheries activities with squid fishing gear and stick-held deep net. This research aims to determine the biological aspects of squid (*Loligo edulis*) such as length frequency distribution, length-weight relationship, sex ratio, gonadal maturity level, gonadal maturity index, size at first caught, and size at first maturity of the gonads. The method used in this research was survey. Sampling measurement of squid using random sampling while surgical sampling using purposive sampling method. This observation was carried out on March 7 to July 30, 2022, at the Belawan Ocean Fishing Port and Tanjung Balai Port. The results showed that the average length distribution of squid was 17.73 cm. The relationship between the length and weight of squid is negative allometric. The sex ratio is 1:1,05. The negative allometric growth pattern is dominated by Gonadal Maturity Level (GML) I and GML II. The highest GML value for male squid was 2.06% at GML III, and the highest GML value for female squid was 1.92% at GML III. The average size of the caught squid length (Lc) is 10.42 cm. The size of the first gonad maturity (Lc) was 13.32 cm.

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Introduction

Geographically, the waters of the Malacca Strait are part of fisheries management areas (WPP) 571 (Arsana, 2014) The northeastern area is directly adjacent to Economic Zones (EEZ) waters of Malaysia, Thailand, and Singapore, the southwest is administratively bordered by the three provinces of the east coast of Sumatra namely the southwest is administratively bordered by the three provinces of the east coast of Sumatra Nangroe Aceh Darussalam, Sumatera Utara dan Riau, to the northwest to the waters of the Andaman Ocean and the southeast to the waters of the southern Natuna Ocean (Wahyudi, 2015).

This region, based on the estimation of fish resource potential (FRP), has 9 (nine) FRP groups, namely large pelagic fish, small pelagic fish, demersal, penaeid shrimp, consumable crayfish, lobsters, crabs, and squid (Faizah and Sadiyah, 2019). This region stretches along the east coast of North Sumatra. The east coast of North Sumatra has a 545 km coast and consists of 7 regencies or cities, namely Langkat Regency, Medan City, Tanjung Balai City, Asahan Regency, Labuhan Batu Regency, Deli Serdang Regency, and Serdang Bedagai Regency. The East Coast of North Sumatra is a busy shipping lane and one of the areas for fishing activities, especially in Belawan Waters. Belawan is a magnet for North Sumatra's fishing activities (Tambunan *et al*., 2010).

The fishery resources in the east coastal area of North Sumatra consist of fish and non-fish resources. One of the non-fish resources is squid. Squids are invertebrates that are classified as pelagic but are sometimes classified as demersal due to their frequent bottom presence. They are members of the mollusk phylum's cephalopod class (Faradizza *et al*., 2019; Surachmat, 2018). Squid fisheries are now one of the potential non-fish resources that have important economic value and are widespread in Indonesian waters (Nababan *et al*., 2017). The tools used are squid nets, stick-held deep nets, squid fishing rods, and by-catches from ring trawls and fish trawls (Ilhamdi and Yahya, 2017).

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The increasing intensity of fishing and the number of fishing fleets as well as the modernization of fishing gear can lead to overfishing. In addition, the high rate of degradation of spawning habitats, the enlargement of squid in coastal areas due to pollution, environmentally unfriendly fishing, sedimentation, and land conversion as a result of development can result in a reduction in squid populations (Baskoro *et al.*, 2017). So, information related to squid fisheries is needed, regarding biological aspects, aspects of capture fisheries, and management efforts.

Therefore, it is necessary to conduct further research. This research aims to analyze various aspects of squid biology and reproduction, including length frequency distribution, length-weight relationship, sex ratio, gonadal maturity level (GML), gonadal maturity index (GMI), length of the first maturity, and length of first captured.

Location and time

This research was carried out from March to May 2022, which months are known as transitional seasons (Ariyanto *et al.*, 2021) and was located at two squid landing locations in the eastern region of North Sumatra which include:

1. Belawan Ocean Fishing Port, Bagan Deli Village, Medan District Belawan City, North Sumatra Province
2. Tanjung Balai Asahan Port, Bagan Asahan Village, Tanjung Balai Teluk Nibung District, North Sumatra Province.

Sampling activities are carried out every day, where 1.5 months are located in Belawan Ocean Fishing Port and the remaining 1.5 months are located in Tanjung Balai Asahan Port.

Data collection

The tools and materials used during the observation are shown in Table 1.

Table 1. Tools and materials

No.	Tools	Specifications	Function
1.	Stationery	-	To log data
2.	Iron Ruler	1 cm	To measure the length of the squid
3.	Plain Paper	-	As a squid base
4.	Digital Scales	1 gram	Measuring squid weight
5.	Tissue	-	To clean the tool
6.	Mobile Camera	48 MP	For documentation of practical activities
7.	Laptop	-	To process data
8.	Squid	-	Samples used
9.	Field Form	-	As a medium for recording data

The data collection method during this research is a direct survey method, namely by looking at and making observations in the field of squid samples that are the target of observations. The data retrieved are primary data and secondary data.

Primary data are obtained from the field such as measurements of length and weight, gender, gonadal maturity level, and others. As well as conducting direct interviews with fishermen or respondents using the questionnaires that have been provided (Mustaqim, 2016; Daud *et al.*, 2020).

Secondary data is obtained from data derived from already available documents. Secondary data can be obtained from various relevant literature, books, agencies, or related institutions (Subagyo, 2020).

Squid measurement sampling used a random sampling method. Dissected sampling was taken using the purposive sampling method.

Data analysis

Squid mantle length frequency distribution

The length frequency distribution is obtained by determining the class interval, middle grade of the class, and the predetermined long frequency distribution in class intervals then calculated using descriptive statistics then presented in the form of graphs (Selvia *et al.*, 2019).

Relationship between length and weight

According to Perangin-angin *et al.,* (2015) the steps to determine the structure of the catch population using data on the length of the mantle are as follows:

1. Specifies the class range (J), with the formula: Range = largest data – narrowed data l
2. Specifies the number of interval classes (C), with the formula: C= 1 + 3.3 log n (n= number of samples)
3. Determining the Length of the class interval (C), using the formula: C= Range/Number of Interval Classes
4. Enter the length of each specimen instance in a predetermined class.

The relationship between length and weight uses a linear allometric model. This model is used to calculate parameters a and b through measurements of length and weight, (Brinkman, 1993):

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

Information:

W: Individual weights of squid (grams)

L: Mantle length (cm)

a. Intercept (intersection of the curve of the relationship of the length of the weight with the y-axis)
b. Slope

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Commented [MOU9]: How many times are samples taken from each regions?

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Linear or straight-line equations are obtained from the following equations:

$L_n\ W(i)=L_n q+bL_n(i)$

Parameters a and b were obtained from Regression Analysis with Ln W as 'y' and Log (i) as 'x', so the regression equation is obtained as follows: $y = a + bx(i)$ (Muhsoni, 2019). The coefficients of determination and correlation can also be determined through equations.

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

1. b < 3: Length gain is faster than weight gain (negative allometry)
2. b = 3: Length gain balanced with weight gain (isometric)
3. b > 3: Weight gain is faster than length gain (positive allometry) (Perangin-angin *et al.*, 2015)

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

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

Information:

b: Exponent value obtained from the analysis

Sb: Standard deviation of the Y value

Furthermore, hypothesis testing is carried out where the t_{value} will be compared with the t_{table} by using a 95% confidence interval. The decision-making is to reject H_0 if the t_{value} is > t_{table} or fail to reject H_0 if the t_{value} is < t_{table}

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

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

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

Information:

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

Length of first Captured (Lc)

Length of first captured according to (Sparre-Venema, 1998):

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

The Lc value is obtained by plotting the percentage of the cumulative frequency of squid caught by its standard length size, where the cut-off point between the curves of 50% cumulative frequency is long when 50% of squid are caught (Tirtadanu and Ernawati, 2016) the value of Lc can be calculated through the formula:

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

Information:

a: Intercept

b: Slope

Length of first Maturity (Lm)

The size length of the first maturity is a variable of the reproductive strategy in squid, besides the sex ratio and spawning periods and types (Barokah *et al.*, 2016). Calculation of the length of the squid length of the first maturity (Lm) using the Spearman-Karber equation method developed by Udupa (Abubakar *et al.*, 2019):

$$m=x_k+\frac{d}{2}-\left(d\sum P_i\right)$$

Information:

m: Logarithms of a long class at the first maturity

d: The difference in the logarithm of the addition of the mid-length value

k: Number of length classes

x_k: Logarithm of the mid-value of the length of the fish that has matured gonads (Pi=1)

Sex Ratio

According to Fisher (1930) the ratio of male to female individuals is estimated at 1:1 naturally in water with a normal spreading population. The equation used to calculate the sex ratio is as follows:

$$\text{Sex Ratio}=\frac{n\ J}{n\ B}$$

Information:

n J: The number of male squids (individuals)

n B: The number of female squids (individuals)

To find out whether there is a real difference between the comparison of male and female individuals, it is carried out through testing and testing 'X^2' (chi-square) with a formula according to (Mchugh, 2013):

$$X^2=\frac{(O-E)^2}{E}$$

Information:

X^2: The cell Chi-square value

O: Frequency of observed male and female squid/ frequency of observation results

E: Expected frequency of male and female squid with a hypothesis (H_0)

The value of $\chi 2$ obtained from this calculation compared with the value of $\chi 2$ in the table with a confidence level of 95% and a free degree (FD) = 1 (one) with the hypothesis:

H_0: There is no noticeable difference between the number of male and female squid

H_1: There is a noticeable difference between the number of male and female squid

If,

X^2 calculate < $\chi 2$ table = H_0 Accepted, H_1 rejected

X^2 calculate > $\chi 2$ table = H_0, Rejected, H_1 accepted (Geraghty, 2015).

Gonadal Maturity Level (GML)

The basis used to determine GML morphologically is the shape, length, color, and development of the gonadal content. Classification of the gonadal maturity level of squid is suggested (Lipiński and Underhill, 1995) in Table 2.

Table 2. The microscopic sexual maturity scale applied for *Loligo edulis*

Maturity Stage	Histological Examination	
	Males	Females
I immature	The first spermatogonia and first primary spermatocytes developed anywhere in the gonad.	The first oogonia developed anywhere in the gonad.
II developing	Tubules with primary spermatocytes inside are clearly defined.	Follicle cells surround the oocyte anywhere in the gonad.
III maturing/ripening,	First spermatids develop anywhere in the gonad.	First invagination of the follicular epithelium.
IV mature/ripe/gravid	First spermatozoa are formed anywhere in the gonad.	Yolk finishes displacing follicular folds in the gonad
V spent	None	First mature oocytes are found anywhere in the gonad.

Gonadal Maturity Index (GMI)

Determining the GMI value of fish can be used the formula below (James, *et. al*., 2010):

$$GMI = \frac{GW}{BW} \times 100\%$$

Information:
GW: Gonadal Weight (grams)
BW: Squid Body Weight (grams)
GMI: Gonadal Maturity Index

Results

Biological Aspects of Squid (*Loligo edulis*)

The squid found at the research location is shown in Figure 1.

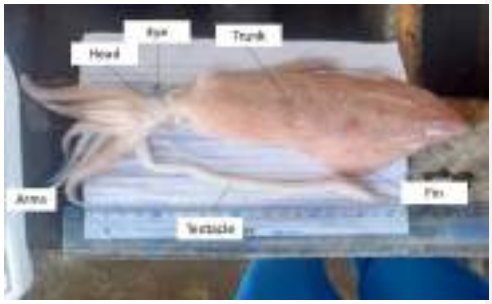

Figure 1 Squid (*Loligo edulis*) found at the research location

Squid Mantle Length Frequency Distribution

Squid sampling (*Loligo edulis*) obtained during research was taken from 2 landing locations located in North Sumatra Province. The results of observations on the distribution of mantle lengths (*Loligo edulis*) for intervals caught and landed at the Ocean Fishing Port of Belawan and Tanjung Balai Asahan Port are presented in Figure 2.

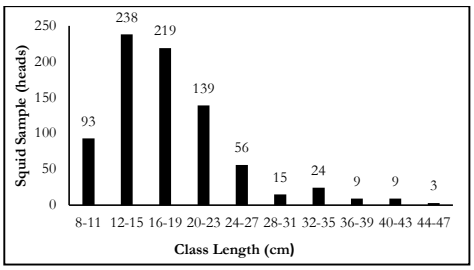

Figure 2 Squid Long Frequency Distribution (*Loligo edulis*)

The maximum and minimum values of squid mantle length are presented in Table 3.

Table 3 Squid Frequency Distribution (*Loligo edulis*)

Location	Number of Samples	Mantle Length		
		Min (cm)	Max (cm)	Average (cm)
Belawan Ocean Fishing Port	455	8	46	18.25
Tanjung Balai Asahan Port	350	8	41	17.05

Weight Length Relationship

The relationship between the length and weight of the squid is presented in Table 4.

Table 4 Relationship of squid weight length (*Loligo edulis*)

Squid Samples	$W = aL^b$	R^2	R	n	T-test	Growth character istic

Squid (*Loligo edulis*)	W= 0.5640L$^{1.9797}$	0,8935	0,9452	805	T_{value}>T_{table} 42,30 > 1,96	Negative allometric

Sex Ratio

The squids that were taken from 2 locations as samples were 80 squids. The samples were dissected to see the characteristics of the gonads which consisted of 42 female squids (53%) and 38 male squids (47%) with a sex ratio = 1.05:1.

To find out whether the squid is in ideal conditions to maintain its sustainability, it is necessary to test the sex ratio value. This test uses a chi-square test with a free degree (FD) 1 and a confidence level of 95 % presented in Table 5.

Table 5 Chi-square test of squid sex ratio at two research locations

Sample	f_0	f_h	$f_0 - f_h$	$(f_0 - f_h)^2$	$(fo-fh)^{EH}fh$	$\sum (f_0 - f_h)^2/f_h$	χ^2_{table}
Male	38	40	-2	4	0,1	0,2	3,84
Female	42	40	2	4	0,1		
Total	80				0,2		

Gonadal Maturity Level (GML)

A sampling of the overall maturity level of the gonads dissected was 80 samples from 805 squid samples measured and weighed obtained from fishermen in the eastern waters of North Sumatra. From the level of gonadal maturity of 80 dissected sample squid caught in the eastern waters of North Sumatra, a level of gonadal maturity varies from GML I to GML IV. The followings are the male GML of squid caught in the Eastern Waters of the Island of Sumatra shown in Table 6.

Table 6 The maturity level of squid gonads

Gender	GML										Sum
	1		2		3		4		5		
	Sum	%	Sum	%	Sum	%	Sum	%	Sum	%	
Male (squid)	16	42	7	18.5	7	18.5	8	21	-	-	38
Female (squid)	6	14	15	36	12	29	9	21	-	-	42
Male and Female (squid)	22	27	22	28	19	24	17	21	-	-	80

Gonadal Maturity Index

Based on the results of the observation that the range values of the Gonadal Maturity Index (GMI) of male and female squids at the research location showed varying amounts. The gonadal maturity index chart is presented in Figures 7 and 8 below.

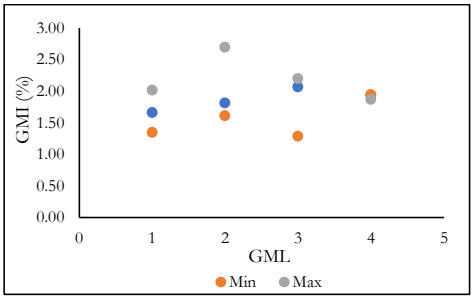

Figure 7 Graph of the maturity index of male squid gonads caught in the eastern waters of North Sumatra

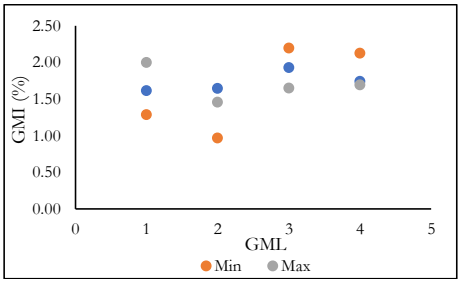

Figure 8 Graph of the maturity index of female squid gonads caught in the eastern waters of North Sumatra.

Length at First Capture (Lc)

The following is a graph of the size first caught on a squid (*Loligo edulis*) caught in the waters east of the island of Sumatra presented in Figure 9.

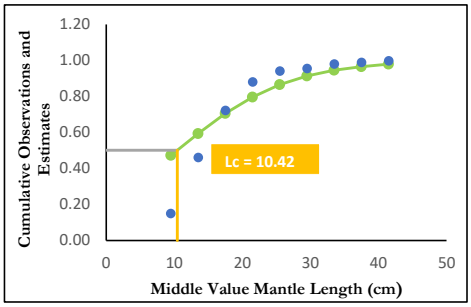

Figure 9 The length of the first time the squid was caught and landed at two study locations

Length at First Maturity (Lm)

Statistical calculations using a confidence level of 95% to estimate squid (*Loligo edulis*) that have entered the maturity category of gonads are presented in Table 6.

Table 6 Length of squid mantle when first maturity gonads (Lm) obtained.

Gender	95% trust	Lc (cm)	Lm (cm)
Combined	12,79 – 13,91 cm	10,42 cm	13.32 cm

The size of the first maturity squid gonads is presented in the diagram in Figure 10 below:

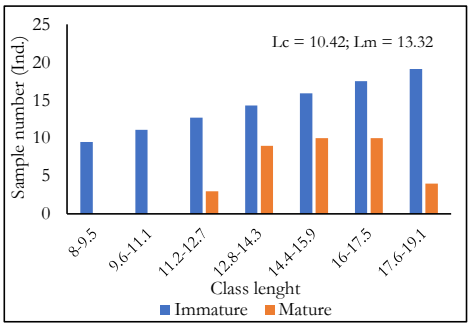

Figure 10 The size of the first maturity squid gonads caught in the waters east of North Sumatra

Discussion

Squid Mantle Length Frequency Distribution

Figure 2 shows the frequency of squid class length landed at 2 squid landing locations in North Sumatra Province totaling 805 squids with a mantle length (cm) ranging from 8–47 cm with an average of 17.73 cm, and a weight range between 26–728 grams with an average of 188.65 grams. The most caught squids ranged from 12–15 cm mantle length class interval of 238, while the fewest caught squids ranged from 3 mantle length class interval.

The average length of this mantle is much bigger when compared to the same type of squid caught in the waters of Belanakan Subang from November 2005 –June 2006. The average length of the *Loligo edulis* mantle caught in Belanakan Subanga at 16.5 cm (Puspasari and Triharyuni, 2013). The difference in size between squid landed at the Ocean fishing port of Belawan and at Tanjung Balai Asahan Port in 2022 and squid landed in Belanakan Subang in 2005–2006 can be caused by several actors, including the differentiation of fishing gear.

Squid landed at the ocean fishing port of Belawan and Tanjung Balai Asahan Port is the catch of squid fishing rods and stick-held deep net (Reza *et al.*, 2019) which operates in areas about 12 miles from the shore, with only a small operating time. Meanwhile, the squid that landed in Belanakan in 2005 was caught by purse seine and danish seine operating on the high seas with the help of lights (Puspasari and Triharyuni, 2013). The lamps used have a power of 750-1.500 watts and amount to 24-90 pieces (Triharyuni *et al.*, 2012).

According to Tasywiruddin (1999), small-sized squids are more commonly caught in waters farther from the coast and small-sized squids are more phototaxis when compared to large-sized squids so that when caught using the help of light, small squids will be caught more. Thus the difference in size that occurred in squid landed in Belanakan in 2005–2006 with squid landed at the ocean fishing port of Belawan and Tanjung Balai Asahan Port in line with the results of his research.

The maximum and minimum values of squid mantle length being presented in Table 3 can be explained as follows: Squid samples (*Loligo edulis*) measured in two locations, namely the Belawan Ocean Fishing Port, totaled 45 squids consisting of 25 female squids and 20 male squids, while in Tanjung Balai Asahan Port 35 squids were consisting of 17 female squids and 18 male squids. The average difference in length obtained in the two locations is in Belawan Ocean Fishing Port of 18.25 cm with a length class interval range of 8-46 cm and Tanjung Balai Asahan Port of 17.05 cm with a long class interval range of 8-41 cm. The difference is not so significant from the size of the squid mantle length in the two areas because the conditions in both environments and the fishing gear used are almost the same.

Weight Length Relationship

The relationship between the length and weight of squid presented in Table 4 shows that the calculated T value is greater than the T-table which can be interpreted as rejecting the null hypothesis (H_0) by showing a negative allometric growth pattern. The equation of the relationship between squid weight lengths in two research locations caught in the eastern waters of North Sumatra is $W = 0.5640L^{1.9797}$ with b value = 1.9797 where the value of b < 3 (negative allometric) which means that the increase in squid length is greater than the increase in squid weight. The correlation value of the squid weight length relationship is $R^2 = 0.8935$ with a value close to 1 which means that the weight length relationship is very closely related (Budiwanto, 2017).

Sex Ratio

The sex ratio of fish can be used as one of the parameters to give an idea of the abundance (Kudale and Rathod, 2016) and balance of fish in the water (Wujdi and Wudianto, 2013). The results of the

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squid's sex ratio shown in figure 4 explained that there are 42 female squids (53%) and 38 male squid (47%) by comparison of sex ratio = 1.05:1. The above conditions according to Limbong and Rahmani (2022) illustrate that the condition of the eastern waters of North Sumatra will quickly recover from fishing activities. Tampubolon *et al.*, (2019) furthermore revealed that the ratio of squid populations as shown in figure 4 in water where the number of male and female fish is balanced, or more female fish will recover faster than a population dominated by male fish.

Based on table 5, $\chi 2$calculation < $\chi 2$table, then H_o was accepted, which means that there is no noticeable difference between the number of male squids and female squids caught and obtained. The findings in the field show that the ratio of females and males is balanced according to Ayorbaba *et al.*, (2019)

Gonadal Maturity Level (GML)

The maturity level of the male squid gonads obtained during the study was dominated by GML I and only a small part of the mature gonads (GML III and IV) were 15 individuals. While the maturity level of the female squid gonads obtained during the study was dominated by GML II and III only a small part of the mature gonads (GML IV) were 9 individuals, see (Figure 6). Based on the data from Figure 6, there are differences in the gonadal maturity level between males and females. This means that the squid is in the gonadal maturity level every month, it is suspected that squid lay eggs throughout the year, while the peak occurs in March and April. This is in line with the reset performed by Pralampita *et al.*, (2002) stated that *L. edulis* in the waters of the Alas Strait spawns all year round, while the peak takes place in March and April. Furthermore, Perangin-angin *et al.*, (2015) explained that the squid spawning throughout the year and reaches its peak when there is an increase in water temperature.

Gonadal Maturity Index

Figures 7 and 8 above showed that the gonadal maturity index (GMI) of male and female squid shows variations. The highest male squid GMI value was found in GMI III at 2.06% and the lowest at 1.66% in GMI I, and the highest female squid GMI value was at GMI III at 1.92% and the lowest at 1.61% in GMI I.

The most dominant GMI was GMI III, both male and female. Where, the GMI value of male squid is greater than the GMI value of female squid (2.06% > 1.92%), which means that when mature, the male squid gonads tend to have a greater weight than female squid because the more mature the gonads had the squid's body will be heavier and will decrease during the reproductive process gradually. The results of the research conducted at the research site are the same as the result of the study by Perangin-angin *et al.*, (2015).

The gonadal maturity index (GMI) needs to be done because it can know changes in the gonads quantitatively (Satyani, 2017). GMI growth is directly proportional to GML, meaning that the higher the GML value, the higher the GMI value (Muharam *et al.*, 2020). When spawning will occur, the GMI will increase in value and reach the maximum limit and will decrease after finishing working (Ridho, 2016). The weight of the gonads was weighed using analytical scales, then the weight of the gonads was compared with the weight of the body and the result was obtained in the form of a percent (%) (Pane, 2020).

Length of first Captured (Lc)

The results of the analysis presented in chart 9 above show that the size of the length of the first captured (Lc) squid as a whole, which amounted to 350 sample squid caught using stick-held deep nets (squid net) fishing gear in the waters east of North Sumatra, was 10.42 cm. interval size range of the mantle length is 8 – 47 cm with a mode in the class of 13.5 cm. Compared to the results of research conducted (Pertiwi *et al.*, 2022), Lc value at the study site (10.42) is smaller than Lc at Tasik Agung Rembang Beach Fishing Port (12.53). This condition shows that there is a higher catch pressure at the study site than at the Tasik Agung Rembang Beach Fishing Port. Efforts that need to be made to the above conditions are to limit arrest attempts by issuing regulations related to this matter. While the remaining 455 squid samples were captured using fishing gear which was not included in the Lc calculation because the data used to calculate Lc only used net fishing gear.

Length at First Maturity (Lm)

It is explained in table 9 above that the results of the calculation of the analysis of the size of the first maturity squid gonads dissected were 13.32 cm. This size range shows that squid has entered the category of mature gonads (range length) between 12.79 to 13.91 cm.

Based on the calculation results in table 6, the value of Lc < Lm or it can be interpreted that the squid is not yet suitable for catching and could grow

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and spawn before being caught. They can also still increase the population of water. In other words, the squid caught has not had time to spawn first.

Research conducted by (Pertiwi *et al.*, 2022) at the Tasik Agung Rembang Beach Fishing Port for squid showed Lm value (16.50 cm) where this result was greater than Lm from the place of study location (13.32). This condition shows that the habitat in the Tasik Agung Rembang Beach Fishing Port area is better than the location where the research was carried out.

The comparison in the two places shows that the Lc obtained is smaller than the Lm where this shows that the squid is not yet suitable for catching and could grow and spawn before being caught. They can also still increase the population of water. In other words, the squid caught has not had time to spawn first.

Conclusion

Based on the results of the research that has been carried out, the following conclusions can be drawn:

1. The most caught squid ranges in the interval of the mantle length class of 12 – 15 cm, while the least caught squid ranges in the interval of the mantle length class 44 – 47.
2. Squids grow allometrically negatively, with a balanced sex ratio of 1:1.05.
3. The maturity level of gonads in male squid shows that GML I is the most dominant (42%), while for females GML II is the most dominant (35.71%). The differences in the phase of maturity of the gonads between males and females mean that the squid is in the gonadal maturity phase every month. It is suspected that the squid spawns throughout the year,
4. The Lc value is smaller than the Lm value (12.45 cm < 13.34cm), which indicates that the caught squid has not had time to spawn first.

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Biological Aspects of Squid (*Loligo edulis*) in The Waters of Eastern North Sumatra

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Fisheries aspect
Management effort

DOI:

ABSTRACT

Squid is one of the non-fish resources that have economic value and is a target species in demersal fisheries activities with squid fishing gear and stick-held deep net. This research aims to determine the biological aspects of squid (*Loligo adults*) such as length frequency distribution, length-weight relationship, sex ratio, gonadal maturity level, gonadal maturity index, size at first caught, and size at first maturity of the gonads. The method used in this research was a survey. Sampling measurement of squid uses random sampling while surgical sampling uses purposive sampling method. This observation was carried out on March 7 to July 30, 2022, at the Belawan Ocean Fishing Port and Tanjung Balai Port. The results showed that the average length distribution of squid was 17.73 cm. The relationship between the length and weight of squid is negative allometric. The sex ratio is 1:1,05. The negative allometric growth pattern is dominated by Gonadal Maturity Level (GML) I and GML II. The highest GML value for male squid was 2.06% at GML III, and the highest GML value for female squid was 1.92% at GML III. The average size of the caught squid length (Lc) is 10.42 cm. The size of the first gonad maturity (Lc) was 13.32 cm.

Introduction

Geographically, the waters of the Malacca Strait are part of fisheries management areas (WPP) 571 (Arsana, 2014) The northeastern area is directly adjacent to Economic Zones (EEZ) waters of Malaysia, Thailand, and Singapore, the southwest is administratively bordered by the three provinces of the east coast of Sumatra namely the southwest is administratively bordered by the three provinces of the east coast of Sumatra Nangroe Aceh Darussalam, Sumatera Utara dan Riau, to the northwest to the waters of the Andaman Ocean and the southeast to the waters of the southern Natuna Ocean (Wahyudi, 2015).

This region, based on the estimation of fish resource potential (FRP), has 9 (nine) FRP groups, namely large pelagic fish, small pelagic fish, demersal, penaeid shrimp, consumable crayfish, lobsters, crabs, and squid (Faizah and Sadiyah, 2019). This region stretches along the east coast of North Sumatra. The east coast of North Sumatra has a 545 km coast and consists of 7 regencies or cities, namely Langkat Regency, Medan City, Tanjung Balai City, Asahan Regency, Labuhan Batu Regency, Deli Serdang Regency, and Serdang Bedagai Regency. The East Coast of North Sumatra is a busy shipping lane and one of the areas for fishing activities, especially in Belawan Waters. Belawan is a magnet for North Sumatra's fishing activities (Tambunan *et al*., 2010).

The fishery resources in the east coastal area of North Sumatra consist of fish and non-fish resources. One of the non-fish resources is squid. Squids are invertebrates that are classified as pelagic but are sometimes classified as demersal due to their frequent bottom presence. They are members of the mollusk phylum's cephalopod class (Faradizza *et al*., 2019; Surachmat, 2018). Squid fisheries are now one of the potential non-fish resources that have important economic value and are widespread in Indonesian waters (Nababan *et al*., 2017). The tools used are squid nets, stick-held deep nets, squid fishing rods, and by-catches from ring trawls and fish trawls (Ilhamdi and Yahya, 2017).

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The increasing intensity of fishing and the number of fishing fleets as well as the modernization of fishing gear can lead to overfishing. In addition, the high rate of degradation of spawning habitats, the enlargement of squid in coastal areas due to pollution, environmentally unfriendly fishing, sedimentation, and land conversion as a result of development can result in a reduction in squid populations (Baskoro *et al.*, 2017). So, information related to squid fisheries is needed, regarding biological aspects, aspects of capture fisheries, and management efforts.

Therefore, it is necessary to conduct further research. This research aims to analyze various aspects of squid biology and reproduction, including length frequency distribution, length-weight relationship, sex ratio, gonadal maturity level (GML), gonadal maturity index (GMI), length of the first maturity, and length of first captured.

Materials and Methods

Location and time

This research was carried out from March to May 2022, which months are known as transitional seasons (Ariyanto *et al.*, 2021) and was located at two squid landing locations in the eastern region of North Sumatra which include:

1. Belawan Ocean Fishing Port, Bagan Deli Village, Medan District Belawan City, North Sumatra Province
2. Tanjung Balai Asahan Port, Bagan Asahan Village, Tanjung Balai Teluk Nibung District, North Sumatra Province.

Sampling activities are carried out every day, where 1.5 months are located in Belawan Ocean Fishing Port and the remaining 1.5 months are located in Tanjung Balai Asahan Port.

Tools and materials

Data collection

The tools and materials used during the observation are shown in Table 1.

Table 1. Tools and materials

No.	Tools	Specifications	Function
1.	Stationery	-	To log data
2.	Iron Ruler	1 cm	To measure the length of the squid
3.	Plain Paper	-	As a squid base
4.	Digital Scales	1 gram	Measuring squid weight
5.	Tissue	-	To clean the tool
6.	Mobile Camera	48 MP	For documentation of practical activities
7.	Laptop	-	To process data
8.	Squid	-	Samples used
9.	Field Form	-	As a medium for recording data

The data collection method during this research is a direct survey method, namely by looking at and making observations in the field of squid samples that are the target of observations. The data retrieved are primary data and secondary data.

Primary data are obtained from the field such as measurements of length and weight, gender, gonadal maturity level, and others. As well as conducting direct interviews with fishermen or respondents using the questionnaires that have been provided (Mustaqim, 2016; Daud, *et al.*, 2020).

Secondary data is obtained from data derived from already available documents. Secondary data can be obtained from various relevant literature, books, agencies, or related institutions (Subagyo, 2020).

Squid measurement sampling (*Lolilogo* sp) used a random sampling method while dissected sampling was taken using the purposive sampling method.

Data analysis

Squid mantle length frequency distribution

The length frequency distribution is obtained by determining the class interval, middle grade of the class, and the predetermined long frequency distribution in class intervals then calculated using descriptive statistics then presented in the form of graphs (Selvia *et al.*, 2019).

Relationship between length and weight

According to Perangin-angin *et al.,* (2015) the steps to determine the structure of the catch population using data on the length of the mantle are as follows:

1. Specifies the class range (J), with the formula: Range = largest data – narrowed data l
2. Specifies the number of interval classes (C), with the formula: C= 1 + 3.3 log n (n= number of samples)
3. Determining the Length of the class interval (C), using the formula: C= Range/Number of Interval Classes
4. Enter the length of each specimen instance in a predetermined class.

The relationship between length and weight uses a linear allometric model. This model is used to calculate parameters a and b through measurements of length and weight, (Brinkman, 1993):

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

Information:

W: Individual weights of squid (grams)

L: Mantle length (cm)

a. Intercept (intersection of the curve of the relationship of the length of the weight with the y-axis)

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Commented [MOU9]: How many times are samples taken from each regions?

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b. Slope

Linear or straight-line equations are obtained from the following equations:

$L_n W(i)=L_n q+bL_n(i)$

Parameters a and b were obtained from Regression Analysis with Ln W as 'y' and Log (i) as 'x', so the regression equation is obtained as follows: $y = a + bx(i)$ (Muhsoni, 2019). The coefficients of determination and correlation can also be determined through equations.

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

1. b < 3: Length gain is faster than weight gain (negative allometry)
2. b = 3: Length gain balanced with weight gain (isometric)
3. b > 3: Weight gain is faster than length gain (positive allometry) (Perangin-angin *et al.*, 2015)

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

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

Information:

b: Exponent value obtained from the analysis

Sb: Standard deviation of the Y value

Furthermore, hypothesis testing is carried out where the t_{value} will be compared with the t_{table} by using a 95% confidence interval. The decision-making is to reject H_0 if the t_{value} is > t_{table} or fail to reject H_0 if the t_{value} is < t_{table}

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

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

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

Information:

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

Length of first Captured (Lc)

Length of first captured according to (Sparre-Venema, 1998):

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

The Lc value is obtained by plotting the percentage of the cumulative frequency of squid caught by its standard length size, where the cut-off point between the curves of 50% cumulative frequency is long when 50% of squid are caught (Tirtadanu and Ernawati, 2016) the value of Lc can be calculated through the formula:

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

Information:

a: Intercept

b: Slope

Length of first Maturity (Lm)

The size length of the first maturity is a variable of the reproductive strategy in squid, besides the sex ratio and spawning periods and types (Barokah *et al.*, 2016). Calculation of the length of the squid length of the first maturity (Lm) using the Spearman-Karber equation method developed by Udupa (Abubakar *et al.*, 2019):

$$m=x_k+\frac{d}{2}-\left(d\sum P_i\right)$$

Information:

m: Logarithms of a long class at the first maturity

d: The difference in the logarithm of the addition of the mid-length value

k: Number of length classes

x_k: Logarithm of the mid-value of the length of the fish that has matured gonads (Pi=1)

Sex Ratio

According to Fisher (1930) the ratio of male to female individuals is estimated at 1:1 naturally in water with a normal spreading population. The equation used to calculate the sex ratio is as follows:

$$\text{Sex Ratio}=\frac{n\ J}{n\ B}$$

Information:

n J: The number of male squids (individuals)

n B: The number of female squids (individuals)

To find out whether there is a real difference between the comparison of male and female individuals, it is carried out through testing and testing 'X^2' (chi-square) with a formula according to (Mchugh, 2013):

$$X^2=\frac{(O-E)^2}{E}$$

Information:

X^2: The cell Chi-square value

O: Frequency of observed male and female squid/ frequency of observation results

E: Expected frequency of male and female squid with a hypothesis (H_0)

The value of $\chi 2$ obtained from this calculation compared with the value of $\chi 2$ in the table with a confidence level of 95% and a free degree (FD) = 1 (one) with the hypothesis:

H_0: There is no noticeable difference between the number of male and female squid

H_1: There is a noticeable difference between the number of male and female squid

If,

X^2 calculate < $\chi 2$ table = H_0 Accepted, H_1 rejected

X^2 calculate > $\chi 2$ table = H_0, Rejected, H_1 accepted (Geraghty, 2015).

Gonadal Maturity Level (GML)

The basis used to determine GML morphologically is the shape, length, color, and development of the gonadal content. Classification of the gonadal maturity level of squid is suggested (Lipiński and Underhill, 1995) in Table 2.

Table 2. The microscopic sexual maturity scale applied for *Loligo edulis*

Maturity Stage	Histological Examination	
	Males	Females
I immature	The first spermatogonia and first primary spermatocytes developed anywhere in the gonad.	The first oogonia developed anywhere in the gonad.
II developing	Tubules with primary spermatocytes inside are clearly defined.	Follicle cells surround the oocyte anywhere in the gonad.
III maturing/ripening,	First spermatids develop anywhere in the gonad.	First invagination of the follicular epithelium.
IV mature/ripe/gravid	First spermatozoa are formed anywhere in the gonad.	Yolk finishes displacing follicular folds in the gonad
V spent	None	First mature oocytes are found anywhere in the gonad.

Gonadal Maturity Index (GMI)

Determining the GMI value of fish can be used the formula below (James, *et. al.*, 2010):

$$GMI = \frac{GW}{BW} \times 100\%$$

Information:
GW: Gonadal Weight (grams)
BW: Squid Body Weight (grams)
GMI: Gonadal Maturity Index

Results

Biological Aspects of Squid (*Loligo edulis*)

The morphological features of the squid obtained are elongated cylindrical shape and the back is tapered with a pair of triangular-shaped fins. Squids found have soft bodies, a pair of eyes next to the head, and five pairs of arms, where one pair of arms is longer than the other called tentacles. The squid found at the research location is shown in Figure 1.

Figure 1 Squid (*Loligo edulis*) found at the research location

Squid Mantle Length Frequency Distribution

Squid sampling (*Loligo edulis*) obtained during research was taken from 2 landing locations located in North Sumatra Province. The results of observations on the distribution of mantle lengths (*Loligo edulis*) for intervals caught and landed at the Ocean Fishing Port of Belawan and Tanjung Balai Asahan Port are presented in Figure 2.

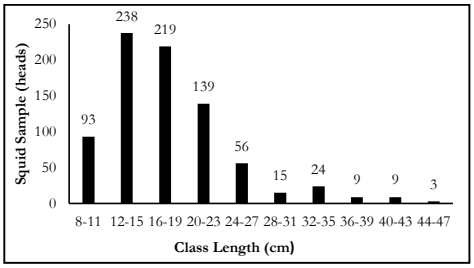

Figure 2 Squid Long Frequency Distribution (*Loligo edulis*)

The maximum and minimum values of squid mantle length are presented in Table 3.

Table 3 Squid Frequency Distribution (*Loligo edulis*)

Location	Number of Samples	Mantle Length		
		Min (cm)	Max (cm)	Average (cm)
Belawan Ocean Fishing Port	455	8	46	18.25
Tanjung Balai Asahan Port	350	8	41	17.05

Weight Length Relationship

The relationship between the length and weight of the squid is presented in Table 4.

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Table 4 Relationship of squid weight length (*Loligo edulis*)

Squid Samples	$W = aL^b$	R^2	R	n	T-test	Growth characteristic
Squid (*Loligo edulis*)	$W = 0.5640L^{1,9797}$	0,8935	0,9452	805	$T_{value} > T_{table}$ 42,30 > 1,96	Negative allometric

Sex Ratio

The squids that were taken from 2 locations as samples were 80 squids. The samples were dissected to see the characteristics of the gonads which consisted of 42 female squids (53%) and 38 male squids (47%) with a sex ratio = 1.05:1.

To find out whether the squid is in ideal conditions to maintain its sustainability, it is necessary to test the sex ratio value. This test uses a chi-square test with a free degree (FD) 1 and a confidence level of 95 % presented in Table 5.

Table 5 Chi-square test of squid sex ratio at two research locations

Sample	f_0	f_h	$f_0 - f_h$	$(f_0 - f_h)^2$	$(fo-fh)^{FH}fh$	$\sum (f_0 - f_h)^2/f_h$	χ^2_{table}
Male	38	40	-2	4	0,1	0,2	3,84
Female	42	40	2	4	0,1		
Total	80				0,2		

Gonadal Maturity Level (GML)

A sampling of the overall maturity level of the gonads dissected was 80 samples from 805 squid samples measured and weighed obtained from fishermen in the eastern waters of North Sumatra. From the level of gonadal maturity of 80 dissected sample squid caught in the eastern waters of North Sumatra, a level of gonadal maturity varies from GML I to GML IV. The followings are the male GML of squid caught in the Eastern Waters of the Island of Sumatra shown in Table 6.

Table 6 The maturity level of squid gonads

Gender	GML										Sum
	1		2		3		4		5		
	Sum	%	Sum	%	Sum	%	Sum	%	Sum	%	
Male (squid)	16	42	7	18.5	7	18.5	8	21	-	-	38
Female (squid)	6	14	15	36	12	29	9	21	-	-	42
Male and Female (squid)	22	27	22	28	19	24	17	21	-	-	80

Gonadal Maturity Index

Based on the results of the observation that the range values of the Gonadal Maturity Index (GMI) of male and female squids at the research location showed varying amounts. The gonadal maturity index chart is presented in Figures 7 and 8 below.

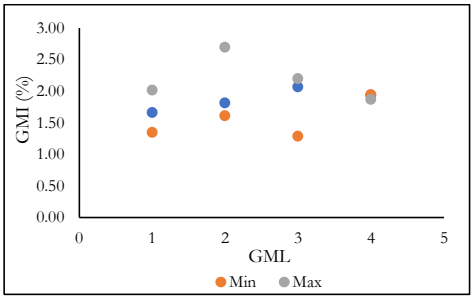

Figure 7 Graph of the maturity index of male squid gonads caught in the eastern waters of North Sumatra

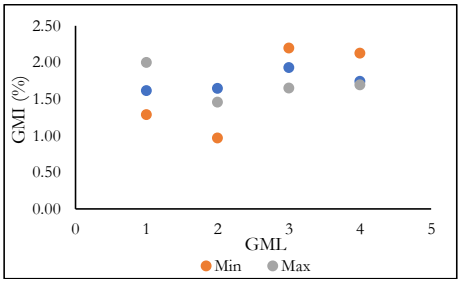

Figure 8 Graph of the maturity index of female squid gonads caught in the eastern waters of North Sumatra.

Length at First Capture (Lc)

The following is a graph of the size first caught on a squid (*Loligo edulis*) caught in the waters east of the island of Sumatra presented in Figure 9.

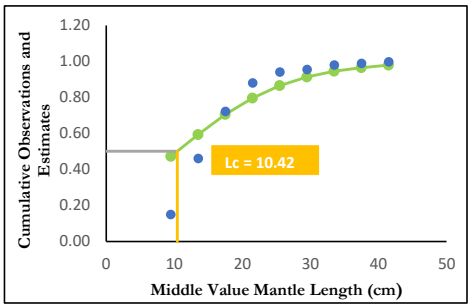

Figure 9 The length of the first time the squid was caught and landed at two study locations

Length at First Maturity (Lm)

Statistical calculations using a confidence level of 95% to estimate squid (*Loligo edulis*) that have entered the maturity category of gonads are presented in Table 6.

Table 6 Length of squid mantle when first cooked gonads (Lm) obtained.

Gender	95% trust	Lc (cm)	Lm (cm)
Combined	12,79 – 13,91 cm	10,42 cm	13.32 cm

The size of the first maturity squid gonads is presented in the diagram in Figure 10 below:

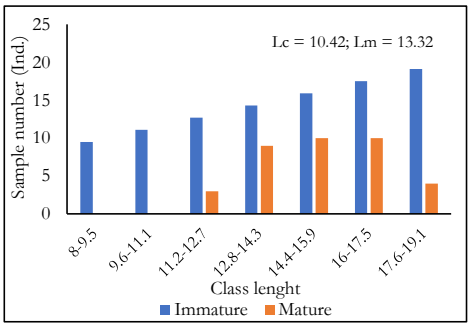

Figure 10 The size of the first maturity squid gonads caught in the waters east of North Sumatra

Discussion

Squid Mantle Length Frequency Distribution

Figure 2 shows the frequency of squid class length landed at 2 squid landing locations in North Sumatra Province totaling 805 squids with a mantle length (cm) ranging from 8–47 cm with an average of 17.73 cm, and a weight range between 26–728 grams with an average of 188.65 grams. The most caught squids ranged from 12–15 cm mantle length class interval of 238, while the fewest caught squids ranged from 3 mantle length class interval.

The average length of this mantle is much bigger when compared to the same type of squid caught in the waters of Belanakan Subang from November 2005 –June 2006. The average length of the *Loligo edulis* mantle caught in Belanakan Subanga at 16.5 cm (Puspasari and Triharyuni, 2013). The difference in size between squid landed at the Ocean fishing port of Belawan and at Tanjung Balai Asahan Port in 2022 and squid landed in Belanakan Subang in 2005–2006 can be caused by several actors, including the differentiation of fishing gear.

Squid landed at the ocean fishing port of Belawan and Tanjung Balai Asahan Port is the catch of squid fishing rods and stick-held deep net (Reza *et al.*, 2019) which operates in areas about 12 miles from the shore, with only a small operating time. Meanwhile, the squid that landed in Belanakan in 2005 was caught by purse seine and danish seine operating on the high seas with the help of lights (Puspasari and Triharyuni, 2013). The lamps used have a power of 750-1.500 watts and amount to 24-90 pieces (Triharyuni *et al.*, 2012).

According to Tasywiruddin (1999), small-sized squids are more commonly caught in waters farther from the coast and small-sized squids are more phototaxis when compared to large-sized squids so that when caught using the help of light, small squids will be caught more. Thus the difference in size that occurred in squid landed in Belanakan in 2005–2006 with squid landed at the ocean fishing port of Belawan and Tanjung Balai Asahan Port in line with the results of his research.

The maximum and minimum values of squid mantle length being presented in Table 3 can be explained as follows: Squid samples (*Loligo edulis*) measured in two locations, namely the Belawan Ocean Fishing Port, totaled 45 squids consisting of 25 female squids and 20 male squids, while in Tanjung Balai Asahan Port 35 squids were consisting of 17 female squids and 18 male squids. The average difference in length obtained in the two locations is in Belawan Ocean Fishing Port of 18.25 cm with a length class interval range of 8-46 cm and Tanjung Balai Asahan Port of 17.05 cm with a long class interval range of 8-41 cm. The difference is not so significant from the size of the squid mantle length in the two areas because the conditions in both environments and the fishing gear used are almost the same.

Weight Length Relationship

The relationship between the length and weight of squid presented in Table 4 shows that the calculated T value is greater than the T-table which can be interpreted as rejecting the null hypothesis (H_0) by showing a negative allometric growth pattern. The equation of the relationship between squid weight lengths in two research locations caught in the eastern waters of North Sumatra is $W = 0.5640L^{1.9797}$ with b value = 1.9797 where the value of b < 3 (negative allometric) which means that the increase in squid length is greater than the increase in squid weight. The correlation value of the squid weight length relationship is $R^2 = 0.8935$ with a value close to 1 which means that the weight length relationship is very closely related (Budiwanto, 2017).

Sex Ratio

The sex ratio of fish can be used as one of the parameters to give an idea of the abundance (Kudale and Rathod, 2016) and balance of fish in the water (Wujdi and Wudianto, 2013). The results of the

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squid's sex ratio shown in figure 4 explained that there are 42 female squids (53%) and 38 male squid (47%) by comparison of sex ratio = 1.05:1. The above conditions according to Limbong and Rahmani (2022) illustrate that the condition of the eastern waters of North Sumatra will quickly recover from fishing activities. Tampubolon *et al.*, (2019) furthermore revealed that the ratio of squid populations as shown in figure 4 in water where the number of male and female fish is balanced, or more female fish will recover faster than a population dominated by male fish.

Based on table 5, $\chi 2$calculation < $\chi 2$table, then H_o was accepted, which means that there is no noticeable difference between the number of male squids and female squids caught and obtained. The findings in the field show that the ratio of females and males is balanced according to Ayorbaba *et al.*, (2019)

Gonadal Maturity Level (GML)

The maturity level of the male squid gonads obtained during the study was dominated by GML I and only a small part of the mature gonads (GML III and IV) were 15 individuals. While the maturity level of the female squid gonads obtained during the study was dominated by GML II and III only a small part of the mature gonads (GML IV) were 9 individuals, see (Figure 6). Based on the data from Figure 6, there are differences in the gonadal maturity level between males and females. This means that the squid is in the gonadal maturity level every month, it is suspected that squid lay eggs throughout the year, while the peak occurs in March and April. This is in line with the reset performed by Pralampita *et al.*, (2002) stated that *L. edulis* in the waters of the Alas Strait spawns all year round, while the peak takes place in March and April. Furthermore, Perangin-angin *et al.*, (2015) explained that the squid spawning throughout the year and reaches its peak when there is an increase in water temperature.

Gonadal Maturity Index

Figures 7 and 8 above showed that the gonadal maturity index (GMI) of male and female squid shows variations. The highest male squid GMI value was found in GMI III at 2.06% and the lowest at 1.66% in GMI I, and the highest female squid GMI value was at GMI III at 1.92% and the lowest at 1.61% in GMI I.

The most dominant GMI was GMI III, both male and female. Where, the GMI value of male squid is greater than the GMI value of female squid (2.06% > 1.92%), which means that when mature, the male squid gonads tend to have a greater weight than female squid because the more mature the gonads had the squid's body will be heavier and will decrease during the reproductive process gradually. The results of the research conducted at the research site are the same as the result of the study by Perangin-angin *et al.*, (2015).

The gonadal maturity index (GMI) needs to be done because it can know changes in the gonads quantitatively (Satyani, 2017). GMI growth is directly proportional to GML, meaning that the higher the GML value, the higher the GMI value (Muharam *et al.*, 2020). When spawning will occur, the GMI will increase in value and reach the maximum limit and will decrease after finishing working (Ridho and Patriono, 2016). The weight of the gonads was weighed using analytical scales, then the weight of the gonads was compared with the weight of the body and the result was obtained in the form of a percent (%) (Pane and Hasanah, 2019).

Length of first Captured (Lc)

The results of the analysis presented in chart 9 above show that the size of the length of the first captured (Lc) squid as a whole, which amounted to 350 sample squid caught using stick-held deep nets (squid net) fishing gear in the waters east of North Sumatra, was 10.42 cm. interval size range of the mantle length is 8 – 47 cm with a mode in the class of 13.5 cm. Compared to the results of research conducted (Pertiwi *et al.*, 2022), Lc value at the study site (10.42) is smaller than Lc at Tasik Agung Rembang Beach Fishing Port (12.53). This condition shows that there is a higher catch pressure at the study site than at the Tasik Agung Rembang Beach Fishing Port. Efforts that need to be made to the above conditions are to limit arrest attempts by issuing regulations related to this matter. While the remaining 455 squid samples were captured using fishing gear which was not included in the Lc calculation because the data used to calculate Lc only used net fishing gear.

Length at First Maturity (Lm)

It is explained in table 9 above that the results of the calculation of the analysis of the size of the first maturity squid gonads dissected were 13.32 cm. This size range shows that squid has entered the category of mature gonads (range length) between 12.79 to 13.91 cm.

Based on the calculation results in table 6, the value of Lc < Lm or it can be interpreted that the squid is not yet suitable for catching and could grow

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and spawn before being caught. They can also still increase the population of water. In other words, the squid caught has not had time to spawn first.

Research conducted by (Pertiwi *et al.*, 2022) at the Tasik Agung Rembang Beach Fishing Port for squid showed an Lm value of (16.50 cm) where this result was greater than the Lm from the place of study location (13.32). This condition shows that the habitat in the Tasik Agung Rembang Beach Fishing Port area is better than the location where the research was carried out.

The comparison in the two places shows that the Lc obtained is smaller than the Lm where which shows that the squid is not yet suitable for catching and could grow and spawn before being caught. They can also still increase the population of water. In other words, the squid caught has not had time to spawn first.

Conclusion

Based on the results of the research that has been carried out, the following conclusions can be drawn:

1. The most caught squid ranges in the interval of the mantle length class of 12 – 15 cm, while the least caught squid ranges in the interval of the mantle length class 44 – 47.
2. Squids grow allometrically negatively, with a balanced sex ratio of 1:1.05.
3. The maturity level of gonads in male squid shows that GML I is the most dominant (42%), while for females GML II is the most dominant (35.71%). The differences in the phase of maturity of the gonads between males and females mean that the squid is in the gonadal maturity phase every month. It is suspected that the squid spawns throughout the year,
4. The Lc value is smaller than the Lm value (12.45 cm < 13.34cm), which indicates that the caught squid has not had time to spawn first.

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Biological Aspects of Squid (*Loligo edulis*) in The Waters of Eastern North Sumatra

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ABSTRACT

Squid is one of the non-fish resources that have economic value and is a target species in demersal fisheries activities with squid fishing gear and stick-held deep net. This research aims to determine the biological aspects of squid (*Loligo edulis*) such as length frequency distribution, length-weight relationship, sex ratio, gonadal maturity level, gonadal maturity index, size at first caught, and size at first maturity of the gonads. The method used in this research was a descriptive survey. The sample collection method used systematic random sampling and purposive sampling techniques. This observation was carried out on March 7 to July 30, 2022, at the Belawan Ocean Fishing Port and Tanjung Balai Port. The results showed that the average length distribution of squid was 17.73 cm. The relationship between the length and weight of squid is negative allometric. The sex ratio is 1:1,05. The negative allometric growth pattern is dominated by Gonadal Maturity Level (GML) I and GML II. The highest GML value for male squid was 2.06% at GML III, and the highest GML value for female squid was 1.92% at GML III. The average size of the caught squid length (Lc) is 10.42 cm. The size of the first gonad maturity (Lc) was 13.32 cm.

Introduction

Geographically, the waters of the Malacca Strait are part of fisheries management areas (WPP) 571 (Arsana, 2014) The northeastern area is directly adjacent to Economic Zones (EEZ) waters of Malaysia, Thailand, and Singapore, the southwest is administratively bordered by the three provinces of the east coast of Sumatra namely the southwest is administratively bordered by the three provinces of the east coast of Sumatera (Aceh, North Sumatera, and Riau) to the northwest to the waters of the Andaman Ocean and the southeast to the waters of the southern Natuna Ocean. This region, based on the estimation of fish resource potential (FRP), has 9 (nine) FRP groups, namely large pelagic fish, small pelagic fish, demersal, penaeid shrimp, consumable crayfish, lobsters, crabs, and squid (Faizah and Sadiyah, 2019).

This region stretches along the east coast of North Sumatra. The east coast of North Sumatra has a 545 km coast and consists of 7 regencies or cities, namely Langkat Regency, Medan City, Tanjung Balai City, Asahan Regency, Labuhan Batu Regency, Deli Serdang Regency, and Serdang Bedagai Regency. The East Coast of North Sumatra is a busy shipping lane and one of the areas for fishing activities, especially in Belawan Waters. Belawan is a magnet for North Sumatra's fishing activities (Tambunan *et al.*, 2010).

The fishery resources in the east coastal area of North Sumatra consist of fish and non-fish resources. One of the non-fish resources is squid. Squids are invertebrates that are classified as pelagic but are sometimes classified as demersal due to their frequent bottom presence. They are members of the mollusk phylum's cephalopod class (Faradizza *et al.*, 2019; Surachmat, 2018). Squid fisheries are now one of the potential non-fish resources that have important economic value and are widespread in Indonesian waters (Nababan *et al.*, 2017). The tools used are squid nets, stick-held deep nets, squid

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fishing rods, and by-catches from ring trawls and fish trawls (Ilhamdi and Yahya, 2017).

The increasing intensity of fishing and the number of fishing fleets as well as the modernization of fishing gear can lead to overfishing. In addition, the high rate of degradation of spawning habitats, the enlargement of squid in coastal areas due to pollution, environmentally unfriendly fishing, sedimentation, and land conversion as a result of development can result in a reduction in squid populations (Baskoro *et al.*, 2017).

Squid (*Loligo* spp.) caught in the waters of Eastern Sumatra is mostly landed at Belawan Ocean Fishing Port (PPS Belawan) and Tanjung Balai Asahan Port. Data on squid catches and fishing efforts in the Eastern Waters of Sumatra landed in Belawan Ocean Fishing Port (PPS Belawan) from 2016 to 2020 on the ecological dimension, technological dimension and social dimension are included in the category of less sustainable. (Chairunnisa, 2022).

The need to maintain squid resources (*Loligo* spp.) is to maintain the potential of squid to be optimally utilized so that there is no overfishing. Therefore, it is necessary to study the basic information on biological aspects, aspects of capture fisheries, and management efforts to support efforts to manage squid resources (*Loligo* spp.) sustainably and the creation of sustainable and environmentally friendly fishing.

Based on the explanation above, it is necessary to conduct research that aims to analyze various aspects of squid biology and reproduction, including length frequency distribution, length-weight relationship, sex ratio, gonadal maturity level (GML), gonadal maturity index (GMI), the length of the first maturity, and the length of first captured.

Materials and Methods

Location and time

This research was carried out from March to May 2022 which months are known as transitional seasons (Ariyanto *et al.*, 2021) and was located at two squid landing locations in the eastern region of North Sumatra which include:

1. Belawan Ocean Fishing Port, Bagan Deli Village, Medan District Belawan City, North Sumatra Province
2. Tanjung Balai Asahan Port, Bagan Asahan Village, Tanjung Balai Teluk Nibung District, North Sumatra Province.

Sampling activities are carried out every day, where 1.5 months are located in Belawan Ocean Fishing Port and the remaining 1.5 months are located in Tanjung Balai Asahan Port.

Tools and materials

Data collection

The tools and materials used during the observation are shown in Table 1.

Table 1. Tools and materials

No.	Tools	Specifications	Function
1.	Stationery	-	To log data
2.	Iron Ruler	1 cm	To measure the length of the squid
3.	Plain Paper	-	As a squid base
4.	Digital Scales	1 gram	Measuring squid weight
5.	Tissue	-	To clean the tool
6.	Mobile Camera	48 MP	For documentation of practical activities
7.	Laptop	-	To process data
8.	Squid	-	Samples used
9.	Field Form	-	As a medium for recording data

The data collection method during this research is a direct survey method, namely by looking at and making observations in the field of squid samples that are the target of observations. The data retrieved are primary data and secondary data.

Primary data are obtained from the field such as measurements of length and weight, gender, gonadal maturity level, and others. As well as conducting direct interviews with fishermen or respondents using the questionnaires that have been provided (Mustaqim, 2016; Daud, *et al.*, 2020).

Secondary data is obtained from data derived from already available documents. Secondary data can be obtained from various relevant literature, books, agencies, or related institutions (Subagyo, 2020).

Squid sampling (*Lolilogo edulis*) used a random sampling method. Dissected sampling was taken using the purposive sampling method

Data analysis

Squid mantle length frequency distribution

The length frequency distribution is obtained by determining the class interval, middle grade of the class, and the predetermined long frequency distribution in class intervals then calculated using descriptive statistics then presented in the form of graphs (Selvia *et al.*, 2019).

Relationship between length and weight

Measurements of total length and weight were performed to compare eating habits based on groups of class length measures(Ismail *et al.*, 2013). According to Perangin-angin *et al.,* (2015) the steps to determine the structure of the catch population using data on the length of the mantle are as follows:

1. Specifies the class range (J), with the formula:
   Range = largest data – narrowed data l

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The number of samples can be seen in the discussion section on the distribution of squid lengths

2. Specifies the number of interval classes (C), with the formula: C= 1 + 3.3 log n (n= number of samples)
3. Determining the Length of the class interval (C), using the formula: C= Range/Number of Interval Classes
4. Enter the length of each specimen instance in a predetermined class.

The relationship between length and weight uses a linear allometric model. This model is used to calculate parameters a and b through measurements of length and weight, (Brinkman, 1993):

$$W=a\ L^b$$

Information:
W: Individual weights of squid (grams)
L: Mantle length (cm)
a. Intercept (intersection of the curve of the relationship of the length of the weight with the y-axis)
b. Slope

Linear or straight-line equations are obtained from the following equations:

$$L_n\ W(i)=L_nq+bL_n(i)$$

Parameters a and b were obtained from Regression Analysis with Ln W as 'y' and Log (i) as 'x', so the regression equation is obtained as follows: $y = a + bx(i)$ (Muhsoni, 2019). The coefficients of determination and correlation can also be determined through equations.

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

1. b < 3: Length gain is faster than weight gain (negative allometry)
2. b = 3: Length gain balanced with weight gain (isometric)
3. b > 3: Weight gain is faster than length gain (positive allometry) (Perangin-angin *et al.*, 2015)

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

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

Information:
t_s = Bailey's t-test,
b = the slope of the linear regression
Sb = standard error of the b coefficients

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

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

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

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

Length of first Captured (Lc)

Length of first captured according to (Sparre-Venema, 1998):

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

The Lc value is obtained by plotting the percentage of the cumulative frequency of squid caught by its standard length size, where the cut-off point between the curves of 50% cumulative frequency is long when 50% of squid are caught (Tirtadanu and Ernawati, 2016) the value of Lc can be calculated through the formula:

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

Information:
a: Intercept
b: Slope

Length of first Maturity (Lm)

The size length of the first maturity is a variable of the reproductive strategy in squid, besides the sex ratio and spawning periods and types (Barokah *et al.*, 2016). Calculation of the length of the squid length of the first maturity (Lm) using the Spearman-Karber equation method developed by Udupa (Abubakar *et al.*, 2019):

$$m=x_k+\frac{d}{2}-\left(d\sum P_i\right)$$

Information:
m: Logarithms of a long class at the first maturity
d: The difference in the logarithm of the addition of the mid-length value
k: Number of length classes
x_k: Logarithm of the mid-value of the length of the fish that has matured gonads (Pi=1)

Sex Ratio

According to (Fisher, 1930) the ratio of male to female individuals is estimated at 1:1 naturally in water with a normal spreading population. The equation used to calculate the sex ratio is as follows:

$$\text{Sex Ratio}=\frac{n\ J}{n\ B}$$

Information:
n J: The number of male squids (individuals)
n B: The number of female squids (individuals)

To find out whether there is a real difference between the comparison of male and female individuals, it is carried out through testing and testing 'X²' (chi-square) with a formula according to (Mchugh, 2013):

$$\Sigma X_{i-j}^2 = \frac{(O-E)^2}{E}$$

Information:
O = Observed (the actual count of cases in each cell of the table)
E = Expected value (calculated below)
χ2 = The cell Chi-square value
∑χ2 = Formula instruction to sum all the cell Chi square values
χ2i-j = i-j is the correct notation to represent all the cells, from the first cell (i) to the last cell (j)

The value of χ2 obtained from this calculation compared with the value of χ2 in the table with a confidence level of 95% and a free degree (FD) = 1 (one) with the hypothesis:
H_0: There is no noticeable difference between the number of male and female squid
H_1: There is a noticeable difference between the number of male and female squid
If,
X^2 calculate < χ2 table = H_0 Accepted, H_1 rejected
X^2 calculate > χ2 table = H_0, Rejected, H_1 accepted (Geraghty, 2015).

Gonadal Maturity Level (GML)

The basis used to determine GML morphologically is the shape, length, color, and development of the gonadal content. Classification of the gonadal maturity level of squid is suggested (Lipiński and Underhill, 1995) in Table 2.

Table 2. The microscopic sexual maturity scale applied for *Loligo edulis*

Maturity Stage	Histological Examination	
	Males	Females
I immature	The first spermatogonia and first primary spermatocytes developed anywhere in the gonad.	The first oogonia developed anywhere in the gonad.
II developing	Tubules with primary spermatocytes inside are clearly defined.	Follicle cells surround the oocyte anywhere in the gonad.
III maturing/ripening,	First spermatids develop anywhere in the gonad.	First invagination of the follicular epithelium.
IV mature/ripe/gravid	First spermatozoa are formed anywhere in the gonad.	Yolk finishes displacing follicular folds in the gonad
V spent	None	First mature oocytes are found anywhere in the gonad.

Gonadal Maturity Index (GMI)

Determining the GMI value of fish can be used the formula below (James, *et. al.*, 2010):

$$GMI = \frac{GW}{BW} \times 100\%$$

Information:
GW: Gonadal Weight (grams)
BW: Squid Body Weight (grams)
GMI: Gonadal Maturity Index

Results

Biological Aspects of Squid (*Loligo edulis*)

The morphological features of the squid obtained are elongated cylindrical shape and the back is tapered with a pair of triangular-shaped fins. Squids found have soft bodies, a pair of eyes next to the head, and five pairs of arms, where one pair of arms is longer than the other called tentacles. The squid found at the research location is shown in Figure 1.

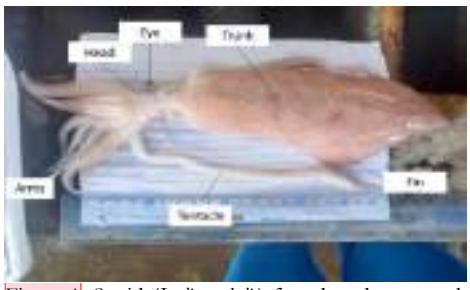

Figure 1. Squid (*Loligo edulis*) found at the research location

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Squid Mantle Length Frequency Distribution

Squid sampling (*Loligo edulis*) obtained during research was taken from 2 landing locations located in North Sumatra Province. The results of observations on the distribution of mantle lengths (*Loligo edulis*) for intervals caught and landed at the Ocean Fishing Port of Belawan and Tanjung Balai Asahan Port are presented in Figure 2.

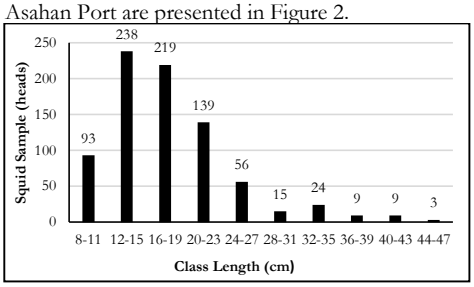

Figure 2. Squid Long Frequency Distribution (*Loligo edulis*)

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The maximum and minimum values of squid mantle length are presented in Table 3.

Table 3. Squid Frequency Distribution (*Loligo edulis*)

Location	Number of Samples	Mantle Length		
		Min (cm)	Max (cm)	Average (cm)
Belawan Ocean Fishing Port	455	8	46	18.25
Tanjung Balai Asahan Port	350	8	41	17.05

Weight Length Relationship

The relationship between the length and weight of the squid is presented in Table 4.

Table 4. Relationship of squid weight length (*Loligo edulis*)

Squid Samples	$W = aL^b$	R^2	R	n	T-test	Growth characteristic
Squid (*Loligo edulis*)	$W = 0.5640L^{1.9797}$	0,8935	0,9452	805	$T_{value} > T_{table}$ 42,30 > 1,96	Negative allometric

Sex Ratio

The squids that were taken from 2 locations as samples were 80 squids. The samples were dissected to see the characteristics of the gonads which consisted of 42 female squids (53%) and 38 male squids (47%) with a sex ratio = 1.05:1.

To find out whether the squid is in ideal conditions to maintain its sustainability, it is necessary to test the sex ratio value. This test uses a chi-square test with a free degree (FD) 1 and a confidence level of 95 % presented in Table 5.

Table 5. Chi-square test of squid sex ratio at two research locations

Sample	f_0	f_h	$f_0 - f_h$	$(f_0 - f_h)^2$	$(fo-fh)^{EH}fh$	$\sum (f_0 - f_h)^2/f_h$	χ^2_{table}
Male	38	40	-2	4	0,1	0,2	3,84
Female	42	40	2	4	0,1		
Total	80				0,2		

Gonadal Maturity Level (GML)

A sampling of the overall maturity level of the gonads dissected was 80 samples from 805 squid samples measured and weighed obtained from fishermen in the eastern waters of North Sumatra. From the level of gonadal maturity of 80 dissected sample squid caught in the eastern waters of North Sumatra, a level of gonadal maturity varies from GML I to GML IV. The followings are the male GML of squid caught in the Eastern Waters of the Island of Sumatra shown in Table 6.

Table 6. The maturity level of squid gonads

Gender	GML										Sum
	1		2		3		4		5		
	Sum	%	Sum	%	Sum	%	Sum	%	Sum	%	
Male (squid)	16	42	7	18.5	7	18.5	8	21	-	-	38
Female (squid)	6	14	15	36	12	29	9	21	-	-	42
Male and Female (squid)	22	27	22	28	19	24	17	21	-	-	80

Gonadal Maturity Index

Based on the results of the observation that the range values of the Gonadal Maturity Index (GMI) of male and female squids at the research location showed varying amounts. The gonadal maturity index chart is presented in Figures 7 and 8 below.

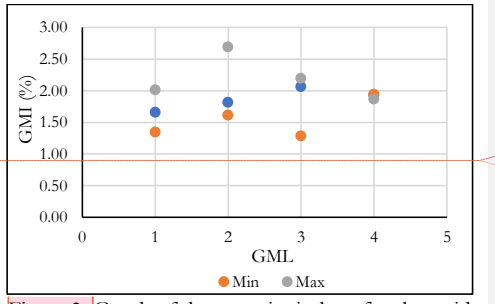

Figure 3. Graph of the maturity index of male squid gonads caught in the eastern waters of North Sumatra

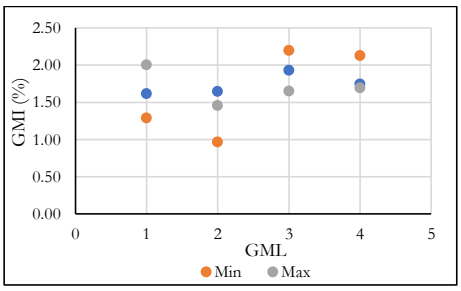

Figure 4 Graph of the maturity index of female squid gonads caught in the eastern waters of North Sumatra.

Length at First Capture (Lc)

The following is a graph of the size first caught on a squid (*Loligo edulis*) caught in the waters east of the island of Sumatra presented in Figure 9.

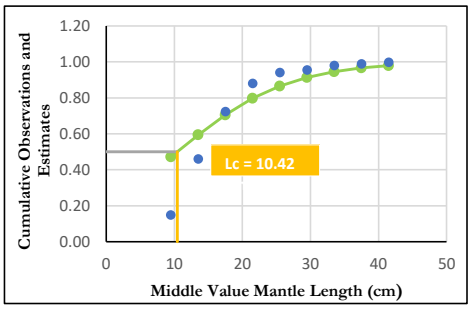

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Figure 5 The length of the first time the squid was caught and landed at two study locations

Length at First Maturity (Lm)

Statistical calculations using a confidence level of 95% to estimate squid (*Loligo edulis*) that have entered the maturity category of gonads are presented in Table 7.

Table 7 Length of squid mantle when first cooked gonads (Lm) obtained.

Gender	95% trust	Lc (cm)	Lm (cm)
Combined	12,79 – 13,91 cm	10,42 cm	13.32 cm

The size of the first maturity squid gonads is presented in the diagram in Figure 10 below:

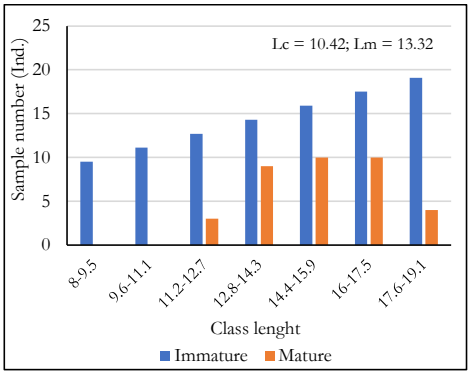

Figure 6 The size of the first maturity squid gonads caught in the waters east of North Sumatra

Discussion

Squid Mantle Length Frequency Distribution

Figure 2 shows the frequency of squid class length landed at 2 squid landing locations in North Sumatra Province totaling 805 squids with a mantle length (cm) ranging from 8–47 cm with an average of 17.73 cm, and a weight range between 26–728 grams with an average of 188.65 grams. The most caught squids ranged from 12–15 cm mantle length class interval of 238, while the fewest caught squids ranged from 3 mantle length class interval.

The average length of this mantle is much bigger when compared to the same type of squid caught in the waters of Belanakan Subang from November 2005 –June 2006. The average length of the *Loligo edulis* mantle caught in Belanakan Subanga at 16.5 cm (Puspasari and Triharyuni, 2013). The difference in size between squid landed at the Ocean fishing port of Belawan and at Tanjung Balai Asahan Port in 2022 and squid landed in Belanakan Subang in 2005–2006 can be caused by several actors, including the differentiation of fishing gear.

Squid landed at the ocean fishing port of Belawan and Tanjung Balai Asahan Port is the catch of squid fishing rods and stick-held deep net (Reza *et al.*, 2019) which operates in areas about 12 miles from the shore, with only a small operating time. Meanwhile, the squid that landed in Belanakan in 2005 was caught by purse seine and danish seine operating on the high seas with the help of lights (Puspasari and Triharyuni, 2013). The lamps used have a power of 750-1.500 watts and amount to 24-90 pieces (Triharyuni *et al.*, 2012).

According to Tasywiruddin (1999), small-sized squids are more commonly caught in waters farther from the coast and small-sized squids are more phototaxis when compared to large-sized squids so that when caught using the help of light, small squids will be caught more. Thus the difference in size that occurred in squid landed in Belanakan in 2005–2006 with squid landed at the ocean fishing port of Belawan and Tanjung Balai Asahan Port in line with the results of his research.

The maximum and minimum values of squid mantle length being presented in Table 3 can be explained as follows: Squid samples (*Loligo edulis*) measured in two locations, namely the Belawan Ocean Fishing Port, totaled 45 squids consisting of 25 female squids and 20 male squids, while in Tanjung Balai Asahan Port 35 squids were consisting of 17 female squids and 18 male squids. The average difference in length obtained in the two locations is in Belawan Ocean Fishing Port of 18.25 cm with a length class interval range of 8-46 cm and Tanjung Balai Asahan Port of 17.05 cm with a long class interval range of 8-41 cm. The difference is not so significant from the size of the squid mantle length in the two areas because the conditions in both environments and the fishing gear used are almost the same.

Weight Length Relationship

The relationship between the length and weight of squid presented in Table 4 shows that the calculated T value is greater than the T-table which can be interpreted as rejecting the null hypothesis (H_0) by showing a negative allometric growth pattern. The equation of the relationship between squid weight lengths in two research locations caught in the eastern waters of North Sumatra is $W = 0.5640L^{1.9797}$ with b value = 1.9797 where the value of b < 3 (negative allometric) which means that the increase in squid length is greater than the increase in squid weight. The correlation value of the squid weight length relationship is $R^2 = 0.8935$ with a value close to 1 which means that the weight length

relationship is very closely related (Budiwanto, 2017).

Sex Ratio

The sex ratio of fish can be used as one of the parameters to give an idea of the abundance (Kudale and Rathod, 2016) and balance of fish in the water (Wujdi; & Wudianto;, 2013). The results of the squid's sex ratio shown in figure 4 explained that there are 42 female squids (53%) and 38 male squid (47%) by comparison of sex ratio = 1.05:1. The above conditions according to Limbong and Rahmani (2022) illustrate that the condition of the eastern waters of North Sumatra will quickly recover from fishing activities. Tampubolon *et al.*, (2019) furthermore revealed that the ratio of squid populations as shown in figure 4 in water where the number of male and female fish is balanced, or more female fish will recover faster than a population dominated by male fish.

Based on table 5, X^2 calculation < X^2 table, then H_o was accepted, which means that there is no noticeable difference between the number of male squids and female squids caught and obtained. The findings in the field show that the ratio of females and males is balanced according to Ayorbaba *et al.*, (2019)

Gonadal Maturity Level (GML)

The maturity level of the male squid gonads obtained during the study was dominated by GML I and only a small part of the mature gonads (GML III and IV) were 15 individuals. While the maturity level of the female squid gonads obtained during the study was dominated by GML II and III only a small part of the mature gonads (GML IV) were 9 individuals, see (Figure 6). There are differences in the phase of maturity of the gonads between males and females. It means that the squid is in the gonadal maturity phase every month, it is suspected that the squid spawns throughout the year, while the peak takes place in March and April.

Gonadal Maturity Index

Figures 7 and 8 above showed that the gonadal maturity index (GMI) of male and female squid shows variations. The highest male squid GMI value was found in GMI III at 2.06% and the lowest at 1.66% in GMI I, and the highest female squid GMI value was at GMI III at 1.92% and the lowest at 1.61% in GMI I.

The most dominant GMI was GMI III, both male and female. Where, the GMI value of male squid is greater than the GMI value of female squid (2.06% > 1.92%), which means that when mature, the male squid gonads tend to have a greater weight than female squid because the more mature the gonads had the squid's body will be heavier and will decrease during the reproductive process gradually. The results of the research cnducted at the research site are the same as the result of the study by Perangin-angin- *et al.*, 2015).

The gonadal maturity index (GMI) needs to be done because it can know changes in the gonads quantitatively (Satyani, 2017). GMI growth is directly proportional to GML, meaning that the higher the GML value, the higher the GMI value (Muharam *et al.*, 2020). When spawning will occur, the GMI will increase in value and reach the maximum limit and will decrease after finishing working (Ridho and Patriono, 2016). The weight of the gonads was weighed using analytical scales, then the weight of the gonads was compared with the weight of the body and the result was obtained in the form of a percent (%) (Pane and Hasanah, 2019).

Length of first Captured (Lc)

The results of the analysis presented in chart 9 above show that the size of the length of the first captured (Lc) squid as a whole, which amounted to 350 sample squid caught using stick-held deep nets (squid net) fishing gear in the waters east of North Sumatra, was 10.42 cm. interval size range of the mantle length is 8 – 47 cm with a mode in the class of 13.5 cm. Compared to the results of research conducted (Pertiwi *et al.*, 2022), Lc value at the study site (10.42) is smaller than Lc at Tasik Agung Rembang Beach Fishing Port (12.53). This condition shows that there is a higher catch pressure at the study site than at the Tasik Agung Rembang Beach Fishing Port. Efforts that need to be made to the above conditions are to limit arrest attempts by issuing regulations related to this matter. While the remaining 455 squid samples were captured using fishing gear which was not included in the Lc calculation because the data used to calculate Lc only used net fishing gear.

Length at First Maturity (Lm)

It is explained in table 9 above that the results of the calculation of the analysis of the size of the first maturity squid gonads dissected were 13.32 cm. This size range shows that squid has entered the category of mature gonads (range length) between 12.79 to 13.91 cm.

Based on the calculation results in table 6, the value of Lc < Lm or it can be interpreted that the squid is not yet suitable for catching and could grow

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and spawn before being caught. They can also still increase the population of water. In other words, the squid caught has not had time to spawn first. Research conducted by (Pertiwi *et al.*, 2022) at the Tasik Agung Rembang Beach Fishing Port for squid showed an Lm value of (16.50 cm) where this result was greater than the Lm from the place of study location (13.32). This condition shows that the habitat in the Tasik Agung Rembang Beach Fishing Port area is better than the location where the research was carried out.

The comparison in the two places shows that the Lc obtained is smaller than the Lm where which shows that the squid is not yet suitable for catching and could grow and spawn before being caught. They can also still increase the population of water. In other words, the squid caught has not had time to spawn first.

Conclusion

Based on the results of the research that has been carried out, the following conclusions can be drawn:

1. The most caught squid ranges in the interval of the mantle length class of 12 – 15 cm, while the least caught squid ranges in the interval of the mantle length class 44 – 47.
2. Squids grow allometrically negatively, with a balanced sex ratio of 1:1.05.
3. The maturity level of gonads in male squid shows that GML I is the most dominant (42%), while for females GML II is the most dominant (35.71%). The differences in the phase of maturity of the gonads between males and females mean that the squid is in the gonadal maturity phase every month. It is suspected that the squid spawns throughout the year,
4. The Lc value is smaller than the Lm value (12.45 cm < 13.34cm), which indicates that the caught squid has not had time to spawn first.

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Biological Aspects of Squid (*Loligo edulis*) in The Waters of Eastern North Sumatra

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ABSTRACT

Squid is one of the non-fish resources that have economic value and is a target species in demersal fisheries activities with squid fishing gear and stick-held deep net. This research aims to determine the biological aspects of squid (*Loligo edulis*) such as length frequency distribution, length-weight relationship, sex ratio, gonadal maturity level, gonadal maturity index, size at first caught, and size at first maturity of the gonads. The method used in this research was a survey. Sampling measurement of squid uses random sampling while surgical sampling uses purposive sampling method. This observation was carried out on March 7 to July 30, 2022, at the Belawan Ocean Fishing Port and Tanjung Balai Port. The results showed that the average length distribution of squid was 17.73 cm. The relationship between the length and weight of squid is negative allometric. The sex ratio is 1:1,05. The negative allometric growth pattern is dominated by Gonadal Maturity Level (GML) I and GML II. The highest GML value for male squid was 2.06% at GML III, and the highest GML value for female squid was 1.92% at GML III. The average size of the caught squid length (Lc) is 10.42 cm. The size of the first gonad maturity (Lc) was 13.32 cm.

Introduction

Geographically, the waters of the Malacca Strait are part of fisheries management areas (WPP) 571 (Arsana, 2014) The northeastern area is directly adjacent to Economic Zones (EEZ) waters of Malaysia, Thailand, and Singapore, the northwest is administratively bordered by the three provinces of the east coast of Sumatra namely the northwest is administratively bordered by the three provinces of the east coast of Sumatra Nangroe Aceh Darussalam, Sumatera Utara dan Riau, to the northwest to the waters of the Andaman Ocean and the southeast to the waters of the southern Natuna Ocean (Wahyudi, 2015).

This region, based on the estimation of fish resource potential (FRP), has 9 (nine) FRP groups, namely large pelagic fish, small pelagic fish, demersal, penaeid shrimp, consumable crayfish, lobsters, crabs, and squid (Faiz and Sadiyah, 2019). This region stretches along the east coast of North Sumatra. The east coast of North Sumatra has a 545 km coast and consists of 7 regencies or cities, namely Langkat Regency, Medan City, Tanjung Balai City, Asahan Regency, Labuhan Batu Regency, Deli Serdang Regency, and Serdang Bedagai Regency. The East Coast of North Sumatra is a busy shipping lane and one of the areas for fishing activities, especially in Belawan Waters. Belawan is a magnet for North Sumatra's fishing activities (Tambunan *et al.*, 2010).

The fishery resources in the east coastal area of North Sumatra consist of fish and non-fish resources. One of the non-fish resources is squid. Squids are invertebrates that are classified as pelagic but are sometimes classified as demersal due to their frequent bottom presence. They are members of the mollusk phylum's cephalopod class (Faradizza *et al.*, 2019; Surachmat, 2018). Squid fisheries are now one of the potential non-fish resources that have important economic value and are widespread in Indonesian waters (Nababan *et al.*, 2017). The tools used are squid nets, stick-held deep nets, squid fishing rods, and by-catches from ring trawls and fish trawls (Ilhamdi and Yahya, 2017).

The increasing intensity of fishing and the number of fishing fleets as well as the modernization of fishing gear can lead to overfishing. In addition, the high rate of degradation of spawning habitats, the enlargement of squid in coastal areas due to pollution, environmentally unfriendly fishing, sedimentation, and land conversion as a result of development can result in a reduction in squid populations (Baskoro *et al.*, 2017). So, information related to squid fisheries is needed, regarding biological aspects, aspects of capture fisheries, and management efforts.

Therefore, it is necessary to conduct further research. This research aims to analyze various aspects of squid biology and reproduction, including length frequency distribution, length-weight relationship, sex ratio, gonadal maturity level (GML), gonadal maturity index (GMI), length of the first maturity, and length of first captured.

Materials and Methods

Location and time

This research was carried out from March to May 2022, which months are known as transitional seasons (Ariyanto *et al.*, 2021) and was located at two squid landing locations in the eastern region of North Sumatra which include:

1. Belawan Ocean Fishing Port, Bagan Deli Village, Medan District Belawan City, North Sumatra Province
2. Tanjung Balai Asahan Port, Bagan Asahan Village, Tanjung Balai Teluk Nibung District, North Sumatra Province.

Sampling activities are carried out every day, where 1.5 months are located in Belawan Ocean Fishing Port and the remaining 1.5 months are located in Tanjung Balai Asahan Port.

Tools and materials

Data collection

The tools and materials used during the observation are shown in Table 1.

Table 1. Tools and materials

No.	Tools	Specifications	Function
1.	Stationery	-	To log data
2.	Iron Ruler	1 cm	To measure the length of the squid
3.	Plain Paper	-	As a squid base
4.	Digital Scales	1 gram	Measuring squid weight
5.	Tissue	-	To clean the tool
6.	Mobile Camera	48 MP	For documentation of practical activities
7.	Laptop	-	To process data
8.	Squid	-	Samples used
9.	Field Form	-	As a medium for recording data

The data collection method during this research is a direct survey method, namely by looking at and making observations in the field of squid samples that are the target of observations. The data retrieved are primary data and secondary data.

Primary data are obtained from the field such as measurements of length and weight, gender, gonadal maturity level, and others. As well as conducting direct interviews with fishermen or respondents using the questionnaires that have been provided (Mustaqim, 2016; Daud, *et al.*, 2020).

Secondary data is obtained from data derived from already available documents. Secondary data can be obtained from various relevant literature, books, agencies, or related institutions (Subagyo, 2020).

Squid measurement sampling (*Loligo* sp) used a random sampling method while dissected sampling was taken using the purposive sampling method.

Data analysis

Squid mantle length frequency distribution

The length frequency distribution is obtained by determining the class interval, middle grade of the class, and the predetermined long frequency distribution in class intervals then calculated using descriptive statistics then presented in the form of graphs (Selvia *et al.*, 2019).

Relationship between length and weight

According to Perangin-angin *et al.*, (2015) the steps to determine the structure of the catch population using data on the length of the mantle are as follows:

1. Specifies the class range (J), with the formula: Range = largest data – r[illegible]owed data l
2. Specifies the number of interval classes (C), with the formula: C= 1 + 3.3 log n (n= number of samples)
3. Determining the Length of the class interval (C), using the formula: C= Range/Number of Interval Classes
4. Enter the length of each specimen instance in a [illegible]edetermined class.

The relationship between length and weight uses a linear allometric model. This model is used to calculate parameters a and b through measurements of length and weight, (Brinkman, 1993):

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

Information:
W: Individual weights of squid (grams)
L: Mantle length (cm)
a. Intercept (intersection of the curve of the relationship of the length of the weight with the y-axis)
b. Slope

Linear or straight-line equations are obtained from the following equations:

$$L_n\ W(i) = L_n q + b L_n(i)$$

Parameters a and b were obtained from Regression Analysis with Ln W as 'y' and Log (i) as 'x', so the regression equation is obtained as follows: $y = a + bx(i)$ (Muhsoni, 2019). The coefficients of determination and correlation can also be determined through equations.

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

1. b < 3: Length gain is faster than weight gain [illegible]egative allometry)
2. b = 3: Length gain balanced with weight gain [illegible]ometric)
3. b > 3: Weight gain is faster than length gain (positive allometry) (Perangin-angin *et al.*, 2015)

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

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

Information:
b: Exponent value obtained from the analysis
Sb: Standard deviation of the Y value

Furthermore, hypothesis testing is carried out where the t_{value} will be compared with the t_{table} by using a 95% confidence interval. The decision-making is to reject H_0 if the t_{value} is > t_{table} or fail to reject H_0 if the t_{value} is < t_{table}

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

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

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

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

Length of first Captured (Lc)

Length of first captured according to (Sparre-Venema, 1998):

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

The Lc value is obtained by plotting the percentage of the cumulative frequency of squid caught by its standard length size, where the cut-off point between the curves of 50% cumulative frequency is long when 50% of squid are caught (Tirtadanu and Ernawati, 2016) the value of Lc can be calculated through the formula:

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

Information:
a: Intercept
b: Slope

Length of first Maturity (Lm)

The size length of the first maturity is a variable of the reproductive strategy in squid, besides the sex ratio and spawning periods and types (Barokah *et al.*, 2016). Calculation of the length of the squid length of the first maturity (Lm) using the Spearman-Karber equation method developed by Udupa (Abubakar *et al.*, 2019):

$$m=x_k+\frac{d}{2}-\left(d\sum P_i\right)$$

Information:
m: Logarithms of a long class at the first maturity
d: The difference in the logarithm of the addition of the mid-length value
k: Number of length classes
x_k: Logarithm of the mid-value of the length of the fish that has matured gonads (Pi=1)

Sex Ratio

According to Fisher (1930) the ratio of male to female individuals is estimated at 1:1 naturally in water with a normal spreading population. The equation used to calculate the sex ratio is as follows:

$$\text{Sex Ratio}=\frac{n\,J}{n\,B}$$

Information:
n J: The number of male squids (individuals)
n B: The number of female squids (individuals)

To find out whether there is a real difference between the comparison of male and female individuals, it is carried out through testing and testing "X^2" (chi-square) with a formula according to (Mchugh, 2013):

$$X^2=\frac{(O-E)^2}{E}$$

Information:
X^2: The cell Chi-square value
O: Frequency of observed male and female squid/ frequency of observation results
E: Expected frequency of male and female squid with a hypothesis (H_0)

The value of $\chi 2$ obtained from this calculation compared with the value of $\chi 2$ in the table with a confidence level of 95% and a free degree (FD) = 1 (one) with the hypothesis:
H_0: There is no noticeable difference between the number of male and female squid
H_1: There is a noticeable difference between the number of male and female squid

If,
X^2 calculate < $\chi 2$ table = H_0 Accepted, H_1 rejected
X^2 calculate > $\chi 2$ table = H_0, Rejected, H_1 accepted (Geraghty, 2015).

Gonadal Maturity Level (GML)

The basis used to determine GML morphologically is the shape, length, color, and development of the gonadal content. Classification of the gonadal maturity level of squid is suggested (Lipiński and Underhill, 1995) in Table 2.

Table 2. The microscopic sexual maturity scale applied for *Loligo edulis*

Maturity Stage	Histological Examination	
	Males	Females
I. Immature	The first spermatogonia and first primary spermatocytes developed anywhere in the gonad	The first oogonia developed anywhere in the gonad

Maturity Stage	Histological Examination	
	Males	Females
II developing	Tubules with primary spermatocytes inside are clearly defined.	Follicle cells surround the oocyte anywhere in the gonad.
III maturing/ripening,	First spermatids develop anywhere in the gonad.	First invagination of the follicular epithelium.
IV mature/ripe/gravid	First spermatozoa are formed anywhere in the gonad.	Yolk finishes displacing follicular folds in the gonad
V spent	None	First mature oocytes are found anywhere in the gonad.

Gonadal Maturity Index (GMI)

Determining the GMI value of fish can be used the formula below (James, *et. al.*, 2010):

$$GMI = \frac{GW}{BW} \times 100\%$$

Information:
GW: Gonadal Weight (grams)
BW: Squid Body Weight (grams)
GMI: Gonadal Maturity Index

Results

Biological Aspects of Squid (*Loligo edulis*)

The morphological features of the squid obtained are elongated cylindrical shape and the back is tapered with a pair of triangular-shaped fins. Squids found have soft bodies, a pair of eyes next to the head, and five pairs of arms, where one pair of arms is longer than the other called tentacles. The squid found at the research location is shown in Figure 1.

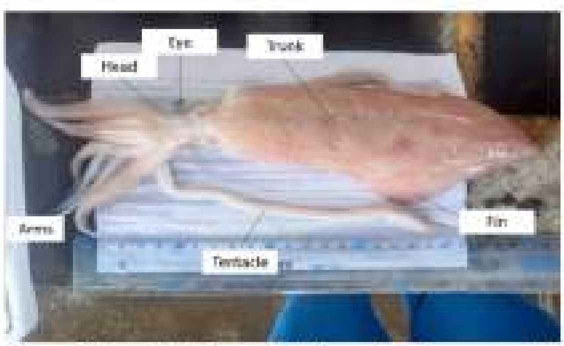

Figure 1 Squid (*Loligo edulis*) found at the research location

Squid Mantle Length Frequency Distribution

Squid sampling (*Loligo edulis*) obtained during research was taken from 2 landing locations located in North Sumatra Province. The results of observations on the distribution of mantle lengths (*Loligo edulis*) for intervals caught and landed at the Ocean Fishing Port of Belawan and Tanjung Balai Asahan Port are presented in Figure 2.

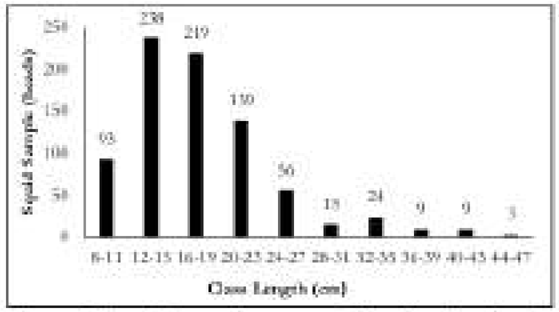

Figure 2 Squid Long Frequency Distribution (*Loligo edulis*)

The maximum and minimum values of squid mantle length are presented in Table 3.

Table 3 Squid Frequency Distribution (*Loligo edulis*)

Location	Number of Samples	Mantle Length		
		Min (cm)	Max (cm)	Average (cm)
Belawan Ocean Fishing Port	455	8	46	18.25
Tanjung Balai Asahan Port	350	8	41	17.05

Weight Length Relationship

The relationship between the length and weight of the squid is presented in Table 4.

Table 4 Relationship of squid weight length (*Loligo edulis*)

Squid Samples	W = aL^b	R²	R	n	T test	Growth character info
Squid (*Loligo edulis*)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Negative allometric

Sex Ratio

The squids that were taken from 2 locations as samples were 80 squids. The samples were dissected to see the characteristics of the gonads which consisted of 42 female squids (53%) and 38 male squids (47%) with a sex ratio = 1.05:1.

To find out whether the squid is in ideal conditions to maintain its sustainability, it is necessary to test the sex ratio value. This test uses a chi-square test with a free degree (FD) 1 and a confidence level of 95 % presented in Table 5.

Table 5 Chi-square test of squid sex ratio at two research locations

Sample	f_o	f_h	$f_o - f_h$	$(f_o - f_h)^2$	$(f_o - f_h)^2/f_h$	$\sum (f_o - f_h)^2/f_h$	χ^2 table
Male	38	40	-2	4	0,1	0,2	3,84
Female	42	40	2	4	0,1		
Total	80				0,2		

Gonadal Maturity Level (GML)

A sampling of the overall maturity level of the gonads dissected was 80 samples from 805 squid samples measured and weighed obtained from fishermen in the eastern waters of North Sumatra. From the level of gonadal maturity of 80 dissected sample squid caught in the eastern waters of North Sumatra, a level of gonadal maturity varies from GML I to GML IV. The followings are the male GML of squid caught in the Eastern Waters of the Island of Sumatra shown in Table 6.

Table 6 The maturity level of squid gonads

Gender	GML										Sum
	I		II		III		IV		V		
	Sum	%	Sum	%	Sum	%	Sum	%	Sum	%	
Male (squid)	12	40	7	23.5	7	23.5	9	31	-	-	35
Female (squid)	9	14	15	36	12	29	9	21	-	-	45
Male and female (squid)	21	27	22	29	19	24	17	21	-	-	80

Gonadal Maturity Index

Based on the results of the observation that the range values of the Gonadal Maturity Index (GMI) of male and female squids at the research location showed varying amounts. The gonadal maturity index chart is presented in Figures 7 and 8 below.

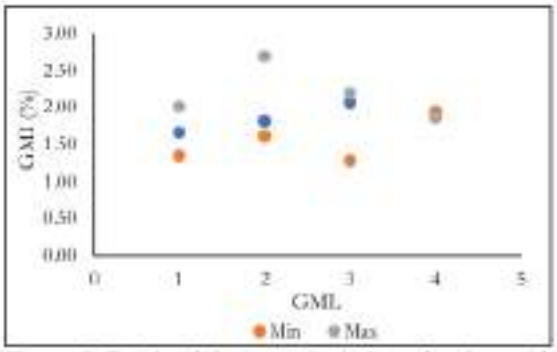

Figure 7 Graph of the maturity index of male squid gonads caught in the eastern waters of North Sumatra

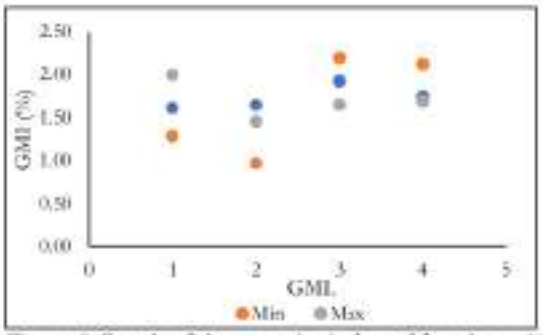

Figure 8 Graph of the maturity index of female squid gonads caught in the eastern waters of North Sumatra.

Length at First Capture (Lc)

The following is a graph of the size first caught on a squid (*Loligo edulis*) caught in the waters east of the island of Sumatra presented in Figure 9.

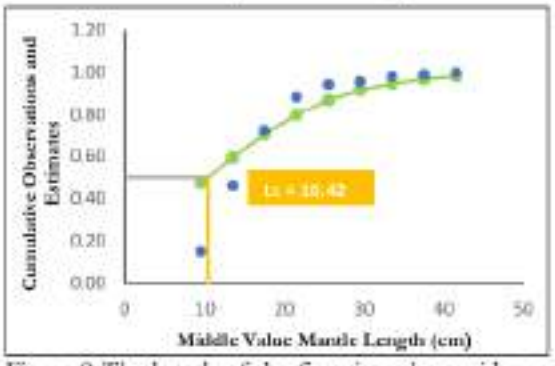

Figure 9 The length of the first time the squid was caught and landed at two study locations

Length at First Maturity (Lm)

Statistical calculations using a confidence level of 95% to estimate squid (*Loligo edulis*) that have entered the maturity category of gonads are presented in Table 6.

Table 6 Length of squid mantle when first cooked gonads (Lm) obtained.

Gender	95% trust	Lc (cm)	Lm (cm)
Combined	12,79 – 13,91 cm	10,42 cm	13.32 cm

The size of the first maturity squid gonads is presented in the diagram in Figure 10 below:

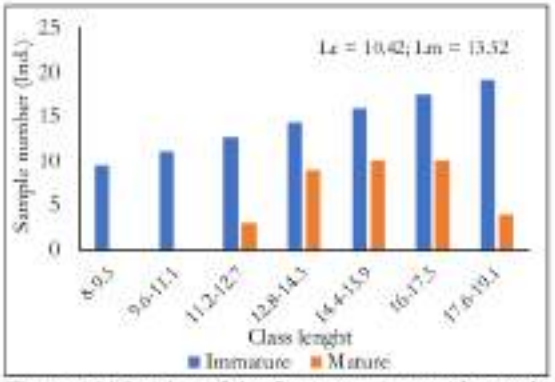

Figure 10 The size of the first maturity squid gonads caught in the waters east of North Sumatra

Discussion

Squid Mantle Length Frequency Distribution

Figure 2 shows the frequency of squid class length landed at 2 squid landing locations in North Sumatra Province totaling 805 squids with a mantle

length (cm) ranging from 8–47 cm with an average of 17.73 cm, and a weight range between 26–728 grams with an average of 188.65 grams. The most caught squids ranged from 12–15 cm mantle length class interval of 238, while the fewest caught squids ranged from 3 mantle length class interval.

The average length of this mantle is much bigger when compared to the same type of squid caught in the waters of Belanakan Subang from November 2005 –June 2006. The average length of the *Loligo* [illegible] mantle caught in Belanakan Subanga at 16.5 cm (Puspasari and Triharyuni, 2013). The difference in size between squid landed at the Ocean fishing port of Belawan and at Tanjung Balai Asahan Port in 2022 and squid landed in Belanakan Subang in 2005–2006 can be caused by several actors, including the differentiation of fishing gear.

Squid landed at the ocean fishing port of Belawan and Tanjung Balai Asahan Port is the catch of squid fishing rods and stick-held deep net (Reza *et al.*, 2019) which operates in areas about 12 miles from the shore, with only a small operating time. Meanwhile, the squid that landed in Belanakan in 2005 was caught by purse seine and danish seine operating on the high seas with the help of lights (Puspasari and Triharyuni, 2013). The lamps used have a power of 750–1.500 watts and amount to 24-90 pieces (Triharyuni *et al.*, 2012).

According to Tasywiruddin (1999), small-sized squids are more commonly caught in waters farther from the coast and small-sized squids are more phototaxis when compared to large-sized squids so that when caught using the help of light, small squids will be caught more. Thus the difference in size that occurred in squid landed in Belanakan in 2005–2006 with squid landed at the ocean fishing port of Belawan and Tanjung Balai Asahan Port in line with the results of his research.

The maximum and minimum values of squid mantle length being presented in Table 3 can be explained as follows: Squid samples (*Loligo edulis*) measured in two locations, namely the Belawan Ocean Fishing Port, totaled 45 squids consisting of 25 female squids and 20 male squids, while in Tanjung Balai Asahan Port 35 squids were consisting of 17 female squids and 18 male squids. The average difference in length obtained in the two locations is in Belawan Ocean Fishing Port of 18.25 cm with a length class interval range of 8-46 cm and Tanjung Balai Asahan Port of 17.05 cm with a long class interval range of 8-41 cm. The difference is not so significant from the size of the squid mantle length in the two areas because the conditions in both environments and the fishing gear used are almost the same.

Weight Length Relationship

The relationship between the length and weight of squid presented in Table 4 shows that the calculated T value is greater than the T-table which can be interpreted as rejecting the null hypothesis (H_0) by showing a negative allometric growth pattern. The equation of the relationship between squid weight lengths in two research locations caught in the eastern waters of North Sumatra is $W = 0.5640 L^{2.9797}$ with b value = 1.9797 where the value of b < 3 (negative allometric) which means that the increase in squid length is greater than the increase in squid weight. The correlation value of the squid weight length relationship is R^2 = 0.8935 with a value close to 1 which means that the weight length relationship is very closely related (Budiwanto, 2017).

Sex Ratio

The sex ratio of fish can be used as one of the parameters to give an idea of the abundance (Kudale and Rathod, 2016) and balance of fish in the water (Wujdi and Wudianto, 2013). The results of the squid's sex ratio shown in figure 4 explained that there are 42 female squids (53%) and 38 male squid (47%) by comparison of sex ratio = 1.05:1. The above conditions according to Limbong and Rahmani (2022) illustrate that the condition of the eastern waters of North Sumatra will quickly recover from fishing activities. Tampubolon *et al.*, (2019) furthermore revealed that the ratio of squid populations as shown in figure 4 in water where the number of male and female fish is balanced, or more female fish will recover faster than a population dominated by male fish.

Based on table 5, χ^2calculation < χ^2table, then H_0 was accepted, which means that there is no noticeable difference between the number of male squids and female squids caught and obtained. The findings in the field show that the ratio of females and males is balanced according to Ayorbaba *et al.*, (2019)

Gonadal Maturity Level (GML)

The maturity level of the male squid gonads obtained during the study was dominated by GML I and only a small part of the mature gonads (GML III and IV) were 15 individuals. While the maturity level of the female squid gonads obtained during the study was dominated by GML II and III only a small part of the mature gonads (GML IV) were 9

individuals, see (Figure 6). Based on the data from Figure 6, there are differences in the gonadal maturity level between males and females. This means that the squid is in the gonadal maturity level every month, it is suspected that squid lay eggs throughout the year, while the peak occurs in March and April. This is in line with the reset performed by Pralampita *et al.*, (2002) stated that *L. edulis* in the waters of the Alas Strait spawns all year round, while the peak takes place in March and April. Furthermore, Perangin-angin *et al.*, (2015) explained that the squid spawning throughout the year and reaches its peak when there is an increase in water temperature.

Gonadal Maturity Index

Figures 7 and 8 above showed that the gonadal maturity index (GMI) of male and female squid shows variations. The highest male squid GMI value was found in GMI III at 2.06% and the lowest at 1.66% in GMI I, and the highest female squid GMI value was at GMI III at 1.92% and the lowest at 1.61% in GMI I.

The most dominant GMI was GMI III, both male and female. Where, the GMI value of male squid is greater than the GMI value of female squid (2.06% > 1.92%), which means that when mature, the male squid gonads tend to have a greater weight than female squid because the more mature the gonads had the squid's body will be heavier and will decrease during the reproductive process gradually. The results of the research conducted at the research site are the same as the result of the study by Perangin-angin *et al.*, (2015).

The gonadal maturity index (GMI) needs to be done because it can know changes in the gonads quantitatively (Satyani, 2017). GMI growth is directly proportional to GML, meaning that the higher the GML value, the higher the GMI value (Muharam *et al.*, 2020). When spawning will occur, the GMI will increase in value and reach the maximum limit and will decrease after finishing working (Ridho and Patriono, 2016). The weight of the gonads was weighed using analytical scales, then the weight of the gonads was compared with the weight of the body and the result was obtained in the form of a percent (%) (Pane and Hasanah, 2019).

Length of first Captured (Lc)

The results of the analysis presented in chart 9 above show that the size of the length of the first captured (Lc) squid as a whole, which amounted to 350 sample squid caught using stick-held deep nets (squid net) fishing gear in the waters east of North Sumatra, was 10.42 cm. interval size range of the mantle length is 8 – 47 cm with a mode in the class of 13.5 cm. Compared to the results of research conducted (Pertiwi *et al.*, 2022), Lc value at the study site (10.42) is smaller than Lc at Tasik Agung Rembang Beach Fishing Port (12.53). This condition shows that there is a higher catch pressure at the study site than at the Tasik Agung Rembang Beach Fishing Port. Efforts that need to be made to the above conditions are to limit arrest attempts by issuing regulations related to this matter. While the remaining 455 squid samples were captured using fishing gear which was not included in the Lc calculation because the data used to calculate Lc only used net fishing gear.

Length at First Maturity (Lm)

It is explained in table 9 above that the results of the calculation of the analysis of the size of the first maturity squid gonads dissected were 13.32 cm. This size range shows that squid has entered the category of mature gonads (range length) between 12.79 to 13.91 cm.

Based on the calculation results in table 6, the value of Lc < Lm or it can be interpreted that the squid is not yet suitable for catching and could grow and spawn before being caught. They can also still increase the population of water. In other words, the squid caught has not had time to spawn first.

Research conducted by (Pertiwi *et al.*, 2022) at the Tasik Agung Rembang Beach Fishing Port for squid showed an Lm value of (16.50 cm) where this result was greater than the Lm from the place of study location (13.32). This condition shows that the habitat in the Tasik Agung Rembang Beach Fishing Port area is better than the location where the research was carried out.

The comparison in the two places shows that the Lc obtained is smaller than the Lm where which shows that the squid is not yet suitable for catching and could grow and spawn before being caught. They can also still increase the population of water. In other words, the squid caught has not had time to spawn first.

Conclusion

Based on the results of the research that has been carried out, the following conclusions can be drawn:

1. The most caught squid ranges in the interval of the mantle length class of 12 – 15 cm, while the least caught squid ranges in the interval of the mantle length class 44 – 47.
2. Squids grow allometrically negatively, with a balanced sex ratio of 1:1.05.

3. The maturity level of gonads in male squid shows that GML I is the most dominant (42%), while for females GML II is the most dominant (35.71%). The differences in the phase of maturity of the gonads between males and females mean that the squid is in the gonadal maturity phase every month. It is suspected that squid spawns throughout the year,
4. The Lc value is smaller than the Lm value (12.45 cm < 13.34cm), which indicates that the caught squid has not had time to spawn first.

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