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Population Growth Model and Mortality of Pakistan Lobster (*Panulirus polyphagus*) in Estuary Waters of Tarakan City

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ABSTRACT

Lobster *Panulirus polyphagus* has a fairly high economic value and is found in the estuary waters of Tarakan City. This research aims to study the growth and mortality model of Lobster *P. polyphagus* originating in the estuary waters of Tarakan City. The research method was carried out using a quantitative descriptive method. Sampling was conducted 14 times from December 2021-May 2022 using gill nets. The results showed that the male sex ratio was more than the female. Allometric growth of males and females is negative allometric with a thin body shape. The structure of the size obtained was mostly in males ranging from 18.3-20.6 cm, and females around 20.5-22.2 cm. The maximum length growth of *P. polyphagus* based on von Bertalanffy's growth model was 31.519 cm in males and 31.374 cm in females. The total mortality (Z) of *P. polyphagus* for males and females was 1.104 and 1.119; catch mortality (F) of 0.106 and 0.253; natural mortality (M) of 0.998 and 0.866; exploitation rate (E) of 0.096 and 0.226, respectively. The high natural mortality causes the extinction of the Lobster species, so good management is needed so that it is sustainable.

1. Introduction

The waters surrounding the estuarine area of Tarakan City have been known as the habitat of many important biological resources for the fishery. One of the important fishery resources is the spiny lobster (*Panulirus* spp). Lobster is an important aquatic resource in Indonesia which has high economic value (Setyanto and Halimah 2019; Setyanto *et al.* 2021) in fact, Indonesia is the third biggest exporter of marine lobsters in the world after Canada and the United States (Garibaldi 2012). Spiny lobsters are a group of crustaceans with no backbone, are hard-skinned, and are covered with thorns (Setyanto *et al.* 2018, 2020). There are six species of spiny lobsters found in Indonesia which are *Panulirus homarus*, *P. longipes*, *P. penicillatus*, *P. ornatus* (Indarjo *et al.* 2023), *P. versicolor* and *P. polyphagus*.

In Indonesia, spiny lobsters are found in several areas, including Aceh's West coast (Suman and Subani 1993; Damora *et al.* 2021). Bali waters (Subani and Prahoro 1990; Suman *et al.* 1993). West Coast Nusa Tenggara (Subani 1984). Kebumen, Central Java (Widianti *et al.* 2021). Cilacap, Gunung Kidul, and Pacitan waters (Setyanto and Halimah 2019). Gunung Kidul waters (Suman *et al.* 2019). Situbondo waters, East Java(Setyanto *et al.* 2019; 2021). Palabuhanratu waters on the coast of West Java (Boer *et al.* 2021). Garut waters, West Java (Pratiwi 2018). Banten waters (Andrykusuma *et al.* 2022). West Papua waters (Wahyudin *et al.* 2017; Situmorang *et al.*

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2021). Seram Island (Wahyudin *et al.* 2016) and in Sebatik island, North Kalimantan Field (Chodrijah *et al.* 2018; Tirtadanu *et al.* 2021).

As for the estuary waters of Tarakan City, three spiny lobster species, namely *P. ornatus, P. versicolor* and *P. polyphagus*, are currently found. Of these three species, the mud spiny lobster (*P. polyphagus*), also known as the Paskitan lobster, is reportedly in high demand for local and international markets (Hargiyatno *et al.* 2013). This lobster can be differentiated from the other spiny lobsters by its light green body color with a yellowish line pattern on each segment and yellow spots on the legset (Carpenter and Neim 1998; Chodrijah *et al.* 2018; Widianti *et al.* 2021). The high market demand and the good retail price could become a major threat to the sustainability of this species (Pranata *et al.* 2017).

However, due to the need for more biological information on this species in the estuarine waters of Tarakan City, sustainable management efforts cannot be effectively developed. Therefore, this study was carried out to establish the growth and mortality model of the mud spiny lobster (*P. polyphagus*) population in the estuarine waters of Tarakan City.

2. Materials and Methods

2.1. Sampling

The sampling was conducted for 5 months, from December 2021 to May 2022, within the estuarine waters of Tarakan City (Figure 1). Samples of the mud spiny lobster (*P. polyphagus*) were obtained from the catches of gill net fishers operating within the area.

The sampling sites were selected based on the purposive sampling method. There were 14 sites, mainly fishing grounds for *P. polyphagus*, chosen for this study. Each sampling was conducted during the low tide for five consecutive days. Data including total length (TL) (Figure 2A), total body weight (TBW) (Figure 2B), and sex of the lobster (Figure 2C and D) were recorded following the method described by Sukamto *et al.* (2017). Other ecological data such as water depth, turbidity, pH, salinity, and temperature in each sampling site were recorded using a multiprobe water quality checker (Dissolved oxygen Analyzer D09100). The data analysis was conducted to obtain the length-weight relationship, sex ratio condition index, size/age structure, von Bertalanffy model, and mortality.

Figure 1. Map of the ecological habitat of *Panulirus polyphagus* in estuary waters of The Tarakan City

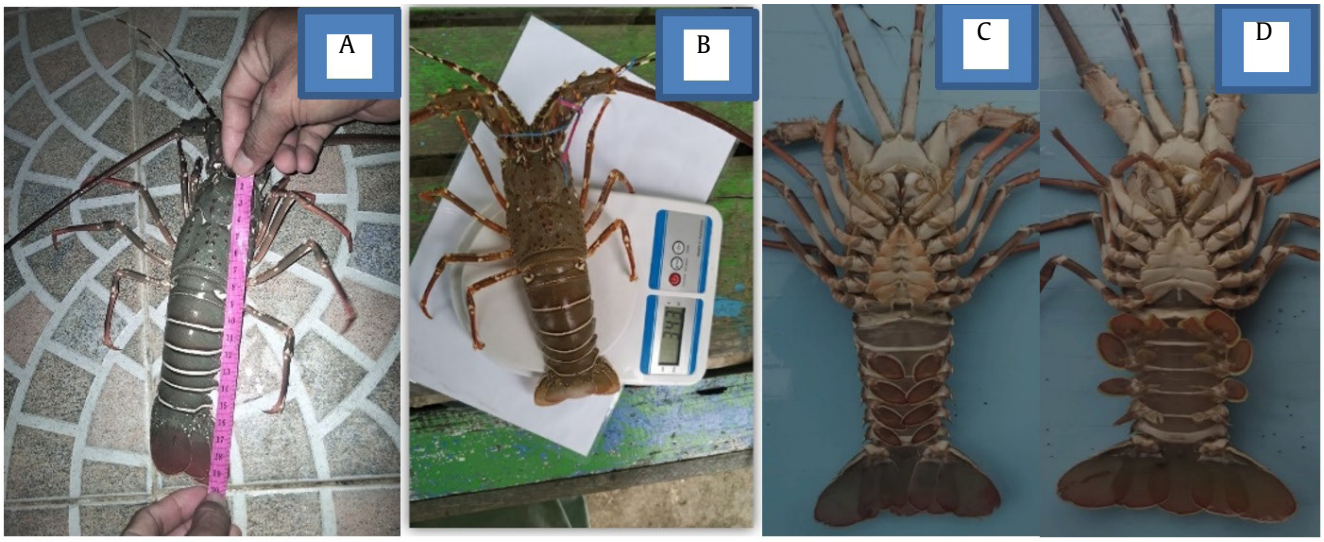

Figure 2. General data of *Panulirus polyphagus* sample. Total Length (TL) (A), total body weight (B), male (C), female (d)

2.2. Data Analysis

2.2.1. Sex Ratio

The sex of the lobster can be marked on the lobster leg (Andrykusuma *et al.* 2022). The sex ratio is a comparison between males and females (Effendie 2002). The lobster samples were sorted according to sex. The sex separation was done according to the swimmerets' size or the lobster Field's pleopod (Kizhakudan and Patel 2010; Ikhwanuddin *et al.* 2014). Male lobster is characterized by smaller swimmerets (Ikhwanuddin *et al.* 2014), the presence of gonopore (in juveniles), and a penile process with a hairy tip in adult lobsters (Kizhakudan and Patel 2010). The female lobster is characterized by a bigger swimmerets (Ikhwanuddin *et al.* 2014) and the presence of an ovigerous setae (Kizhakudan and Patel 2010). The male and female ratio of the *P. polyphagus* population in the estuarine waters of Tarakan City was then calculated by dividing the number of males by the number of females.

Testing the normality of sex ratio data using Chi-Square by comparing the normal curve of the collected data (B) with standard normal curve data (A). Normal distribution data if the B value is not significantly different from the A value (Sugiono 2017).

The data normality test method with Chi Square (χ^2) is as follows:

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

Whereas:
χ^2 = chi-square distribution
O_i = observation value *i*
E_i = expected value *i*

The data is stated to be normally distributed if the calculated Chi Square value < the Chi Square table value, while the data is stated to be abnormally distributed if the calculated Chi Square value > the Chi Square table value (Sugiono 2017).

2.2.2. Length Weight Relationship

The length of the lobster samples was measured from the tip of the posterior margin of the orbit to the tip of the telson to the nearest 0.1 cm following (Indarjo *et al.* 2023) using the vernier caliper. The total body weight was measured using a digital balance to the nearest 0.1 g. Then, the length-weight relationship of male and female *P. polyphagus* was estimated following the model suggested by Effendie (1979) as follows:

$$Y = a + X^b \text{ or } \text{Log } Y = \text{Log } a + b \text{ Log } X$$

Whereas:
Y = total weight of *P. polyphagus* (g)
X = total length of *P. polyphagus* (mm)
a+b = constant (intercept)

2.2.3. Condition Index

Condition indexs of the *P. polyphagus* were grouped into five categories i.e., very flatfish/

flatcrustacea (0.01-0.50), flatfish/flatcrustacea (0.51-0.99), proportional/ideal fish or crustacea (1.00), fat fish (1.01-1.50), and the obese fish or crustacea (>1.50) (Firdaus *et al.* 2020; Indarjo *et al.* 2021, 2023; Salim *et al.* 2021, 2022). Meanwhile, the allometric growth and the isometric growth were analyzed based on the methods Field Weatherley (1972) and Field Lagler (1949) suggested Lagler (1949), respectively. The condition factors of the isometric and allometric of lobster were then calculated following Lagler (1949) and Weatherley (1972), respectively.

The condition factor with isometric growth characteristic was calculated using the following equation:

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

Whereas:
W = total weight of *P. polyphagus* (g)
L = total length of *P. polyphagus* (mm)
10^5 = the equation was taken, so $K_{(TI)}$ value is close to 1

The condition factor of lobster with allometric growth characteristic was calculated using the following equation:

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

Whereas:
W = total weight of of *P. polyphagus* (g)
$\hat{W}$ = allegation of the total weight of *P. polyphagus* (g)
W = $a L^b$ obtained using the regression equation of length-weight correlation

Condition factors can describe the body shape of an aquatic species(Salim *et al.* 2020; Indarjo *et al.* 2020, 2021). The classification of the condition factor in this study followed Salim *et al.* (2020) as follows: very thin (0.01-0.49), thin (0.5-0.99), proportional (1.00), fat (1.01-1.50), and very fat (>1.50).

2.2.4. Absolute Growth

The absolute growth of the *P. polyphagus* was estimated using von Bertalanffy's growth model (Sparre and Venema 1999) as follow:

$$Lt = L\infty\ (1-e^{-k(t-t0)})$$

Whereas:
Lt = length of *P. polyphagus* at age t (unit of time)
L∞ = the theoretical maximum length of *P. polyphagus* (asymptotic length)
K = *P. polyphagus* growth coefficient (per unit time)
t_0 = the theoretical age of *P. polyphagus* when the length is zero

2.2.5. Age Structure

The age structure of the *P. polyphagus* was analyzed using the mode class shift method associated with the von Bertalanffy's growth model (Sparre and Venema 1999):

$$(\Delta L/\Delta t) = (L_2 - L_1) / (t_2 - t_1)$$

$$L_{(t)} = (L_2 + L_1)$$

Whereas:
L/Δt = relative growth of *P. polyphagus*
L = length *P. polyphagus*
t = difference in sampling time *P. polyphagus*
$L_{(t)}$ = average length of mode by plotting the values of $L_{(t)}$ and (ΔL/Δt), a linear equation can be derived as follows

$$Y = a + bx$$

Whereas:
a = $((\sum y/n) - (b\ (\sum x/n)))$
b = $(n\sum(xy) - (\sum x)(\sum y)) / (n\sum x^2 - (\sum x)^2)$

This linear regression equation was then used to estimate the asymptotic length (L∞) and the growth coefficient (K) of *P. polyphagus*. The theoretical age of the *P. polyphagus*, when the length is equal to zero, can be estimated separately using an empirical equation suggested by Pauly (1984) as follows:

$$Log\ (-t_0) = 0.3922 - 0.275\ (Log\ L\infty 1.038\ (Log\ K)$$

Where:
L∞ = asymptotic length (cm)
K = growth coefficient
t_0 = hypothetical age at length equals to zero (years)

2.2.6. Mortality

The natural mortality (M) of the *P. polyphagus* was estimated using the empirical formula of Pauly (1984), as follows:

$$\text{Log M} = 0.0066 \text{ x } 0.279 \log L\infty + 0.6543 \log K + 0.4634 \log T$$

The total mortality (Z) of the *P. polyphagus* was estimated using the Beverton and Holt formula (Sparre and Venema 1999) as follows:

$$Z = K \cdot \left[\frac{L\infty - \bar{L}}{\bar{L} - L'}\right]$$

The fishing mortality (F) of the *P. polyphagus* was estimated according to the following equation:

$$F = Z - M$$

Finally, the exploitation rate (E) of the *P. polyphagus* in sampling sites was estimated following Pauly (1984) as follows:

$$E = F / (F + M)$$

3. Results

3.1. Water Parameters

The water depth where the lobsters were caught varied from 18-30 meters. The pH ranged from 7.05 to 7.33, whereas the salinity ranged from 15-18 ppt. The water brightness ranged from 1.9-2.12 m and the temperature ranged from 26-29°C.

3.2. Sex Ratio

The total number of mud-spiny lobster (*P. polyphagus*) obtained during the study was 83 individuals, which included 55 males (66.3%) and 28 females (33.7%) (Table 1). The sex ratio male and female of the mud-spiny in the estuarine waters of Tarakan city was estimated at 1.96:1. Based on the Chi-Square test, the Chi Square value is 1.94 and the Chi Critical Value is 12.59 with a probability value of 0.96 (Table 2).

3.3. Length Weight Relationship

The male mud-spiny lobster population recorded a total length that ranged from 8.7 to 30 cm and the total weight ranged from 91 to 831 g. Meanwhile, the female lobster population recorded a total length that ranged from 12.5 to 28.6 cm and the total weight ranged from 143 to 703 g.

The length-weight relationship of male *P. polyphagus* was recorded at 0.2951, the value of b was 1.6006 where the R^2 value was 0.554 with a correlation value of 0.774. While the female lobster *P. polyphagus* recorded length-weight relationship of 0.6281, b of 1.4027, and R^2 value of 0.5288 with a correlation value of 0.727 (Figure 3).

3.4. Condition Index

The results revealed that the male population of mud-spiny lobster in the estuarine waters of Tarakan city can be grouped into 4 categories including the thin body shape (0.5-0.99) with a percentage of 53%; proportional body shape (1.00) with a percentage of 2%; fat body shape (1.01-1.50) with a percentage of 38% and very fat body shape (> 1.50) by 7% (Figure 4).

Meanwhile, the female population of the mud-spiny lobster can be grouped into 3 categories, namely thin body shape with a percentage of 50%; fat body shape with a percentage of 43%, and very fat body shape with a percentage of 7%.

3.5. Structure Age and Absolute Growth

The size structure of the male mud-spiny lobster ranged from 18.3-20.6 cm (16 samples) which is estimated to be 39-48 days old. The female lobster was found to range from 45-53 cm (8 samples) with estimated age that ranged from 49 to 56 days old. The absolute growth of male and female lobsters

Table 2. Chi square value and chi critical value and probability sex ratio

Test	Chi square	Chi-critical value	Probability
Value	1.94	12.59	0.96

Table 1. Observed and expected sex ratio of *Panulirus polyphagus* in the estuarine waters of Tarakan City

Observed	Male	Female	Total	Expected	Male	Female
1st week	16	7	23	1st week	15.2	7.8
2nd week	7	4	11	2nd week	7.3	3.7
3rd week	7	3	10	3rd week	6.6	3.4
4th week	18	8	26	4th week	17.2	8.8
5th week	3	2	5	5th week	3.3	1.7
6th week	1	2	3	6th week	2.0	1.0
7th week	3	2	5	7th week	3.3	1.7
Total sample	55	28	83			

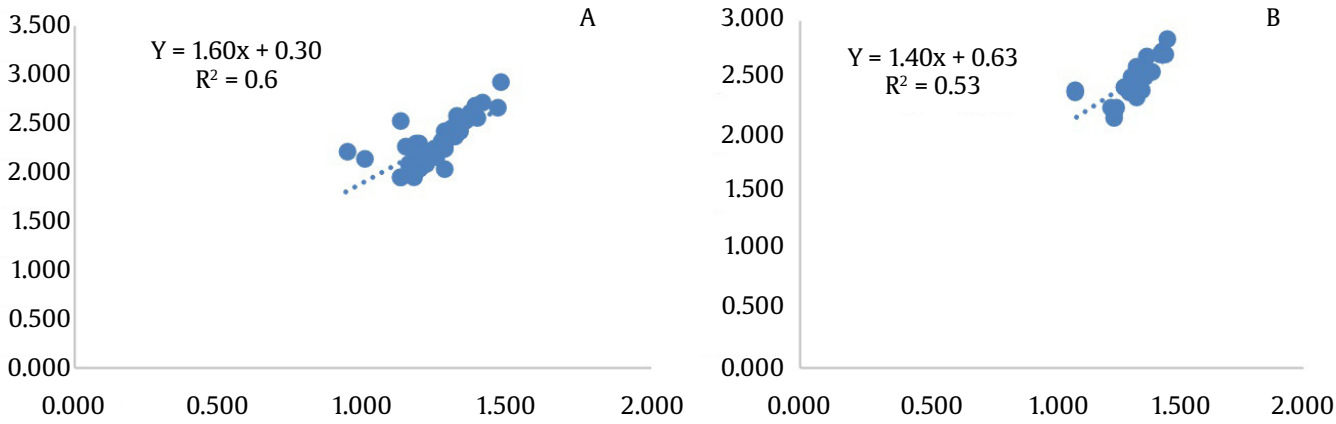

Figure 3. Length weight relationship male (A) and female (B)

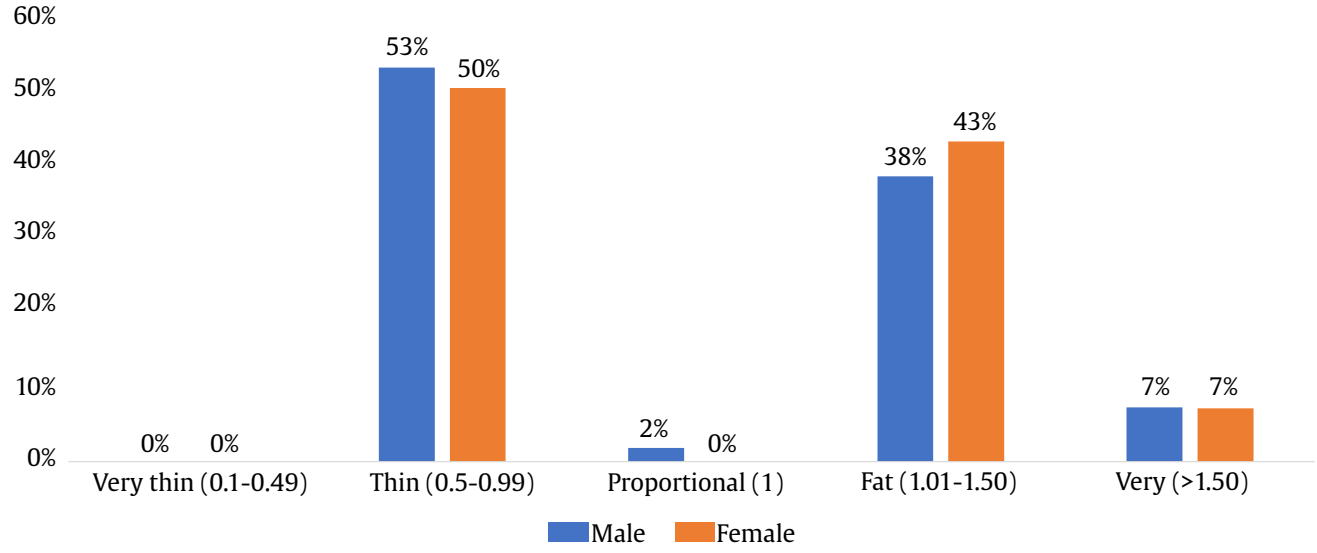

Figure 4. Condition index male (left) and female (right)

can be estimated by the following equations: y = -0.0214x + 0.6745 with a correlation value of 0.95 and y = -0.0211x + 0.662 with a correlation value of 0.90 (Figure 5). The growth model of male lobster based on the von Bertalanffy can be estimated by the following equation: $y = -4E\text{-}14x^6 + 7E11x^5 - 6E\text{-}08x^4 + 2E\text{-}05x^3 - 0.01x^2 + 0.60x + 1.32$ with a correlation value of 0.99. The growth model for female lobster can be estimated using the following equation: $y = -7E\text{-}14x^6 + 1E10x^5 - 8E08x^4 + 3E\text{-}05X^3 - 0.01x^2 + 0.61x + 1.19$ with a correlation value of 0.99 (Figure 6). Using the von Bertalanffy growth model, the length of male and female lobsters at the age of zero days was estimated to be 1.14 cm and 1.20 cm, respectively. The smallest male and female specimens caught during the sampling were 8.7 cm and 12.5 cm which are estimated to be 14 days and 20 days old, respectively. While the largest specimens were 30 cm and 28.6 cm which are estimated to be 140 days and 114 days old, respectively. The growth rate of male and female lobsters was estimated at 0.02 cm/year and 0.02 cm/year, respectively.

3.6. Mortality

Based on the Beverton and Holt formula, the total mortality (Z) of the male and female mud-spiny lobster population in the estuarine waters of Tarakan city was estimated to be at 1.10 and 1.12. The fishing (F) or catch mortality (M) for male and female lobsters was estimated at 0.11 and 0.25, respectively. The natural mortality for males and females was estimated at 0.99 and 0.89, respectively. The exploitation rate for males and females was recorded at 0.09 and 0.23, respectively (Figure 7).

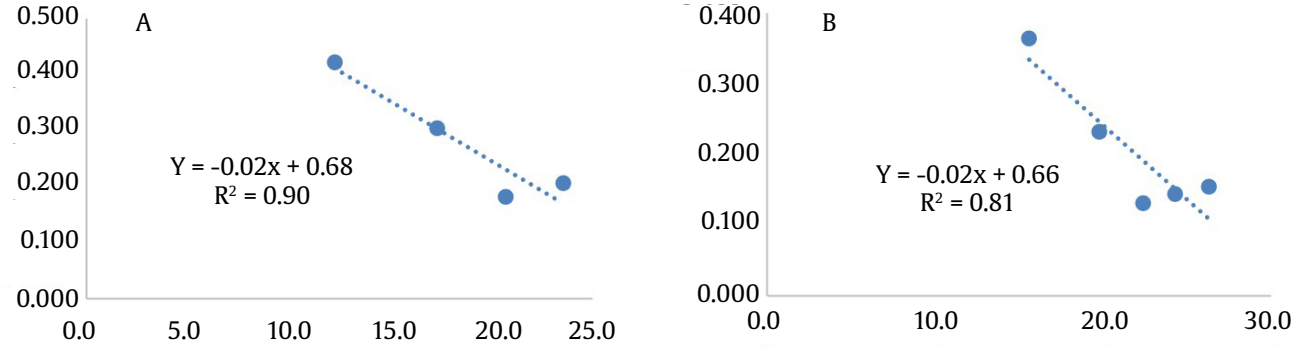

Figure 5. Absolute growth male (A) dan female (B)

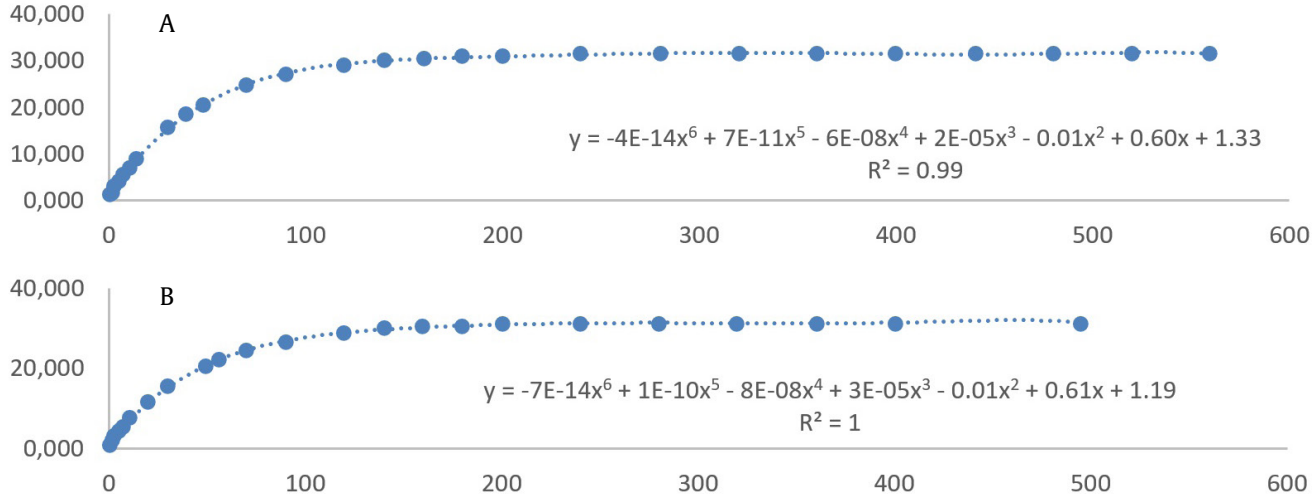

Figure 6. Model von bertalanffy male (A) and female (B)

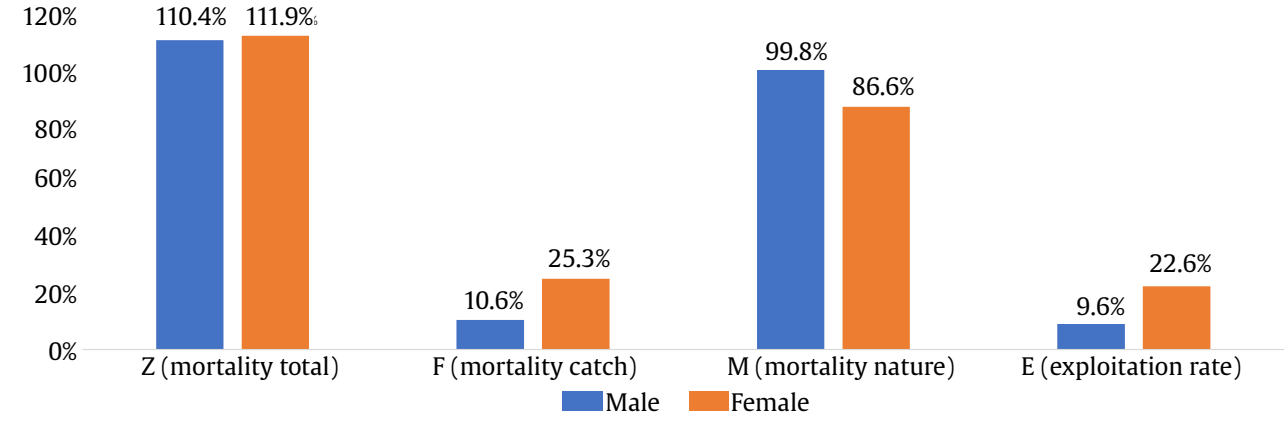

Figure 7. Mortality male (left) and female (right)

4. Discussion

This study observed that the sex of the mud-spiny lobster population in the estuarine waters of Tarakan city is dominated by male individuals. Based on the Chi Square Test in Table 1 and 2, it explains that there is no difference in the proportion sex ratio between males and females where the data is normally distributed (Sugiono 2017). This is not a surprise because several studies also recorded similar findings, such as in the waters of Johor Malaysia, got sex ratio of male and female *P. polyphagus* 3.34:1

out of 300 individuals (Ikhwanuddin 2014; Waiho *et al.* 2021). However, there is study in other waters in North Kalimantan, namely Sebatik Island waters, that shown different sex ratio of male and female *P. polyphagus*, namely 1:1.15 out of 921 individuals (Chodrijah *et al.* 2018).

The difference in the dominance of lobster catches can be influenced by environmental conditions such as salinity, fishing pressure (Little and Watson 2005; Pranata *et al.* 2017), pH, temperature (Anguilar-Alberola and Mesquita-Joanes 2014), and water depth. Meanwhile, factors that affect the abundance of lobsters include light intensity, water current, dissolved oxygen, and temperature (Nugroho 2007). The sex ratio of the mud-spiny lobster (Ann and Zakariam 2018) in the estuarine waters of Tarakan city is close to balance which indicates good population health (Yusuf *et al.* 2019). According to Widianti *et al.* (2021), mud-spiny lobsters are normally found at the depth of lesser than 16 meters. They also prefer muddy and sandy bottom areas. Different ecological (temperature and salinity) and biological (sex ratio) factors could affect the growth pattern of lobsters (Froose 2006; Damora *et al.* 2018).

Based on the length-weight relationships, it was found that the male and female *P. polyphagus* in the estuarine waters of Tarakan city exhibited b value of less than 3.0. This shows that the growth pattern of the mud-spiny lobster population in the area is characterized by negative allometric (Effendi 2002; Muttaqin *et al.* 2016; Salim *et al.* 2020; Indarjo *et al.* 2021). This deviated from the finding of Waiho *et al.* (2021) who reported that the female *P. polyphagus* was characterized by negative allometric, but the male lobster was growing in a positive allometric. However, Ikhwanuddin (2014) found the male and female *P. polyphagus* populations in the water of Johore, Malaysia was growing in a negative allometric. The finding of the present study is also in agreement with the finding of Chodrijah *et al.* (2018) who also found that the male and female *P. polyphagus* population in Sebatik Island, North Kalimantan exhibited negative allometric growth. According to Fazhan *et al.* (2021), the negative allometric growth could be contributed to the health condition (Hossain *et al.* 1987; Steinback *et al.* 2008; Datta *et al.* 2013), environmental factors (Nahdi *et al.* 2016) and to certain extend, sample size (Fazhan *et al.* 2021).

The condition factor, K, is widely used in fisheries and fish biology studies as a measure of the degree of robustness of fish. Condition index values (K) are widely used in the fish biology study literature and can be used on crustaceans as a measure of the degree of fish sturdiness (Indarjo *et al.* 2021) and fish body shape (Indarjo *et al.* 2020; Salim *et al.* 2020).

While the research results of female *P. polyphagus* lobsters obtained 3 categories, namely thin body shape with a percentage of 50%, fat body shape with a percentage of 43% and very fat body shape with a percentage of 7%. The results of the K value on the body shape of crustaceans in the cultivation scale were obtained in the range between 0.97-1.17 (Kunda *et al.* 2018) and body shape in the range between 0.79-1.00 was the body shape in nursery conditions and the range was 1.14 based on the parent village (Lalrinsanga *et al.* 2012).

Based on the size structure, males were found at most 18.3–20.6 cm and females were found at 20.5-22.2 cm. In the regression equation, the von Bertalanffy model is obtained where the maximum length growth in male lobsters is obtained at a size of 31.519 cm with an estimated age of 560 days. While the maximum length growth in female lobsters was found at a size of 31.374 cm with an estimated age of 495 days. This maximum length growth of *P. polyphagus* in estuarine waters of the Tarakan city was higher than in Sebatik Island waters, North Kalimantan, Indonesia with 12.41 cm (Chodrijah *et al.* 2018), and also in Veraval waters, India, with 13.5 cm for male and 12.47 cm for female (Kizhakudan *et al.* 2013).

The value of male mortality is higher than females in natural mortality, but in total mortality, fishing mortality and exploitation rate, female values are higher than males. This indicates that female lobsters have a fairly high mortality compared to female lobsters, but the highest mortality is caused by natural mortality and not fishing mortality and exploitation rates are in the rational and sustainable category so that sustainable management of Pakistani lobster is needed in the Tarakan city by domestication of spiny lobster *P. polyphagus*. Biological growth and mortality information can be used in the management of fisheries resources for sustainable development and rational exploitation.

However, from lobster research found in Sebatik waters (North Kalimantan, Indonesia) different

results were obtained, where the E value from the results of Chodrijah *et al.* (2018) research was 0.61 (61%)/year this caused the condition of lobsters in the waters. Sebatik in the category of normal threshold/ high exploitation rate (over exploitation) According to Yudiati *et al.* (2020) explained that the rate of overexploitation is caused by high market demand and attractive price values.

The natural mortality of male *P. polyphagus* was recorded as higher than females. This is particularly worrisome as it will become a threat to the sustainability of the mud-spiny lobster fishery in the estuarine waters of Tarakan city. Unlike the lobster population in Sebatik Island waters, the low exploitation level (E<0.5) of the mud-spiny lobster in the estuarine waters of Tarakan city implies that the fishing activity has not yet been considered a major threat to the sustainability of the lobster population in the area (Pauly 1983; Indarjo *et al.* 2020, 2021). However, good management practices should be developed to avoid the exploitation level becoming higher in the future.

In conclusion, the mud-spiny lobster *Panulirus polyphagus* population in the estuarine waters of Tarakan city was dominated by males. Both male and female mud-spiny lobsters exhibited negative allometric growth. The natural mortality (M) of the male population is higher than the female population. Nevertheless, the lobster population in estuarine waters of The Tarakan City is still under or less exploitation. However, the high natural mortality among male lobsters is a concern that warrants further investigation.

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