HAYATI
Journal of Biosciences

Vol. 30 No. 3, May 2023 532-542
DOI:10.4308/hjb.30.3.532-542
ISSN: 1978-3019
EISSN: 2086-4094

Growth Patterns and Mortality of Lobster *Panulirus ornatus* from the Catch of Bottom Gill Net Fishers in the Western Waters of Tarakan Island

Agus Indarjo[1*], Gazali Salim[2], Thonas Indra Maryanto[3], Ngungut[2], Laurha Annisa Linting[2], Muhammad Firdaus[2], Rozi[4], Rukisah[5]

[1]*Department of Marine Science, Faculty of Fisheries and Marine Science, Diponegoro University Semarang, Semarang 50275, Indonesia*
[2]*Department of Aquatic Resource Management, Faculty of Fisheries and Marine Science, Borneo University, Tarakan 77115, Indonesia*
[3]*Department of Geodesy Engineering, Faculty of Civil Engineering and Planning, Institut Teknologi Nasional Bandung, Bandung 40124, Indonesia*
[4]*Department of Fish Health Management And Aquaculture, Faculty of Fisheries and Marine, Airlangga University, Surabaya 60115, Indonesia*
[5]*Department of Fisheries Aquaculture, Universitas Borneo Tarakan, Tarakan 77115, Indonesia*

ARTICLE INFO

Article history:
Received July 13, 2022
Received in revised form September 20, 2022
Accepted November 11, 2022

KEYWORDS:
Growth patterns,
Mortality,
Panulirus ornatus,
Population,
Tarakan

ABSTRACT

Large-bodied *Panulirus ornatus* lobsters are economically important because they are an aquatic biota. It is one of the most important commodities in the city of Tarakan. The aim is to analyze the growth patterns and mortality of *P. ornatus* from the West Waters of Tarakan City. Method using a quantitative descriptive. The purposive sampling method was used by dragging the gill net fishing gear to the *P. ornatus* lobster ground area, and the collection was carried out 16 times in 7 months (December 2021-July 2022). The results of *P. ornatus* showed that the male sex ratio was higher than the female. The growth model was allometrically negative, and the criteria for the condition index were fat and thin. The growth pattern of Model Von Bertalanffy males is slower than females. However, the growth rate to achieve asymptotic growth for males is faster than for females. The total mortality, catch mortality, and exploitation rate of males was higher than females. However, the mortality of the female nature was higher than that of males. *P. ornatus* should be managed in the waters of West Tarakan using the domestication and restocking technique to increase sustainability.

1. Introduction

The diverse coastal ecosystems related to estuaries and seas in Tarakan waters include a variety of biological resources (Salim *et al.* 2021). In January 2022, the aquatic ecosystem was determined to be estuarine with a salinity of approximately 15-18 ppt. The waters from the Sulawesi Sea, the Pacific Ocean, and the South China Sea converge in the Tarakan estuary, resulting in vast marine biological resources, including bivalves, Pisces, and crustaceans (Salim *et al.* 2021). According to Garibaldi (2012), 19 types of lobster in the genus Panulirus inhabit the tropics and possess high economic value in fishery production. *P. ornatus* lobster is a highly sought-after crustacean in global fisheries due to its elevated price and enormous size (Ng *et al.* 2022; Wahyudin *et al.* 2017a).

The characteristics of *P. ornatus*, according to Wahyudin *et al.* (2017b), are round and have a spiny carapace, anterior spines of varying sizes, and the height of the frontal horn is twice the height of the eye, without any thorns in between. Flagella antennae are longer than the peduncle, and the plate at the base has two pairs of prominent spines, four pairs without a clamp, and the mouth is without indentation. The tail fan section is soft and flexible, and the total length of the males reaches 13.5-13.9 cm. Meanwhile, the total weight and length reach 94-107 grams and 14.6-14.8 cm. The *P. ornatus* is found in the northwestern Indo-Pacific area, East Africa, southern Japan Solomon Islands, Papua New Guinea, Australia, New Caledonia, and Fiji (Wahyudin

* Corresponding Author
E-mail Address: indarjoa@yahoo.com

et al. 2017a). Dao *et al.* (2015) and Dao and Jones (2015) explained that the management of tropical *P. ornatus* lobsters is complicated due to its wide species distribution and a homogeneous population that spans several countries and marine waters. Anh and Jones (2015) and Anh and Jones (2015a) stated that Vietnam has a stable and sustainable fishery production of *P. ornatus* with a relatively uniform catch for more than 15 years. Furthermore, Priyambodo *et al.* (2020) reported that fishing for *P. ornatus* in Indonesia is relatively new, appears much larger, and has different species compositions.

Different habitat areas and distribution patterns of lobsters are determined to obtain different catches (Bahrawi *et al.* 2015a, 2015b; Indris and Bahrawi 2015; Jones *et al.* 2019; Priambodo *et al.* 2015). Lobster catches are obtained by choosing the sites according to the preferred ecology (Priyambodo *et al.* 2017; Chodrijah *et al.* 2018). Indo-Pacific waters close to the equator (tropical) are known to be the preferred habitat (Utomo *et al.* 2018). Additionally, *P. ornatus* lobsters prefer rocky, shallow, and murky waters. (Saputra *et al.* 2020; Setyanto *et al.* 2018, 2019, 2020, 2021) explained that the species has a critical economic value; therefore, management is needed to protect the sustainability of the species in Indonesian waters. The species has a relatively high economic value with a price of approximately IDR 600,000/kg, which increased to IDR 1,300,000/kg in December 2021 due to a decrease in catches. On average, 5 individuals were obtained in 2020, but only 1-2 without *P. ornatus* were caught in December 2021. Foo (2020) stated that there is a decrease in the population of lobster due to its global demand as a delicacy.

The increase in the sale price results from the volume caught and the strong market demand from the domestic community. Furthermore, the problem with *P. ornatus* lobsters is the degradation in size and weight. The field survey conducted in February 2020 identified species of 42.6-52.2 cm in length and 247-435.5 grams in weight. On the contrary, the field survey at the beginning of the preliminary research in December 2021 reported a total length of 20-25 cm with a weight of 235-368 grams. The biological component of the morphology of *P. ornatus* lobsters in the Tarakan city waters has deteriorated during the past year, both in total length and weight. However, this is different from the research by Utomo *et al.* (2018), who stated that the growth has increased, reaching a weight of approximately 6.5 kg per head. The preferred ecological habitat is Indo-Pacific waters, equatorial (tropical) areas (Setyanto *et al.* 2021). The lobsters can live in slightly cloudy, rocky, and shallow habitats (Setyanto *et al.* 2019).

The interviews gathered that five boats actively used the Bottom Gill Net to catch lobster. Furthermore, Setyanto and Halimah (2019) stated that the net is adequate fishing gear for catching lobster. The three species caught were bamboo lobster (*P. versicolor*), Pakistani lobster (*P. polyphagus*), and lobster *P. ornatus*. However, the one most commonly found was *P. polyphagus*, while *P. versicolor* and *P. ornatus* were rare.

According to Setyanto *et al.* (2021), the existence of regulations regarding lobster fisheries management can provide information about sustainability. Therefore, the significance of the biological characteristics requires further study. This should play a crucial role in the policy of adult lobster populations to obtain an overview of the distribution of sex ratio, growth, condition index, and mortality at a specific space and time. The research on lobsters with high economic value (Wardiatno *et al.* 2016), such as *Panulirus femoristriga* Von Martens on Sulawesi and Seram Islands, and their diversity in Palabuhanratu Bay, South Java, have complemented the new distribution record of Panulirus ornatus, *P. polyphagus* and *Parribacus antarcticus* by Wahyudin *et al.* (2017b). There is no result on the growth and mortality model of *P. ornatus* in the waters of Tarakan city.

Consequently, this research is essential for the survival of *P. ornatus* in terms of knowledge, comprehension, and its natural habitat. Managing the exploitation of this species, including the annual reproduction system, requires knowledge according to there is no finding on the growth and mortality model of lobster *P. ornatus* in the waters of the city of Tarakan. Consequently, this research is essential for the survival of *P. ornatus* in terms of knowledge, comprehension, and its natural habitat. Managing the exploitation of this species, including the annual reproduction system, requires knowledge, according to Priyambodo *et al.* (2020). There is a need for sustainable fisheries management. Therefore, growth and mortality modelling is needed to monitor natural stock and reduce overfishing activities, which can be done by conducting aquaculture businesses using the domestication model (Foo 2020).

2. Materials and Methods

2.1. Sampling

Research on *P. ornatus* lobster was carried out for 7 months, from December 2021 to July 2022. The sample was a *P. ornatus* lobster caught by bottom gill net fishermen in the western part of Tarakan City waters, as shown in Figure 1. The method used was a descriptive quantitative approach. Furthermore, the location was determined through the purposive sampling of 16 points based on the *P. ornatus* fishing habitat. Sampling was carried out based on the occurrence of low tide (5 days), namely the first (early), third (middle) and fifth (late) days. The number of samples obtained by fishermen ranged from 1-3 lobsters (the fishermen's catch is uncertain).

2.2. Data Collection

The lobsters used in this study were selected based on Total Length (TL) (Figure 2), Total Weight (TW), and sex, while water quality parameters used were depth, brightness, pH, salinity, temperature, and DO (*in situ*). The resulting data was sex ratio, growth characteristics regarding the length-weight relationship, condition index, Von Bertalanffy model, age structure, and mortality. Data were analyzed through SPSS or Excel and presented in the form of charts or graphs.

2.3. Data Analysis

2.3.1. Sex Ratio

According to Andrykusuma *et al.* (2022), the sex of a lobster can be identified from the lobster leg. The determining characteristic of a male *P. ornatus* is the walking legs. The 5th (pereopod) is pointed, sharp, and protruding, and the base of the carapace (thoracic sternum) is relatively rougher and not triangular, and the female lobster has a third leg (pereopod) with a hole in it. The female lobster has a third leg (pereopod) with a hole, while the 5th (pereopod) is pointed, sharp, and protruding. Furthermore, the base of the carapace (thoracic sternum) is relatively rougher and not triangular. *P. ornatus* males have a single swimming leg (pleopod) shaped like a leaf and a protrusion of the genitals (gonophore) at the base of the fifth walking stalk, which is related to the testes. It also possesses a pair of swimming legs (pleopod) shaped like two leaves termed exopleody and endopleody Sukamto *et al.* (2017). Effendie (2002) stated that the sex ratio compares males and females.

2.3.2. Length-Weight Relationship

Length-weight relationship of the *P. ornatus* collected by fishermen's catches in the West Waters

Figure 2. Sample Lobster *P. ornatus*

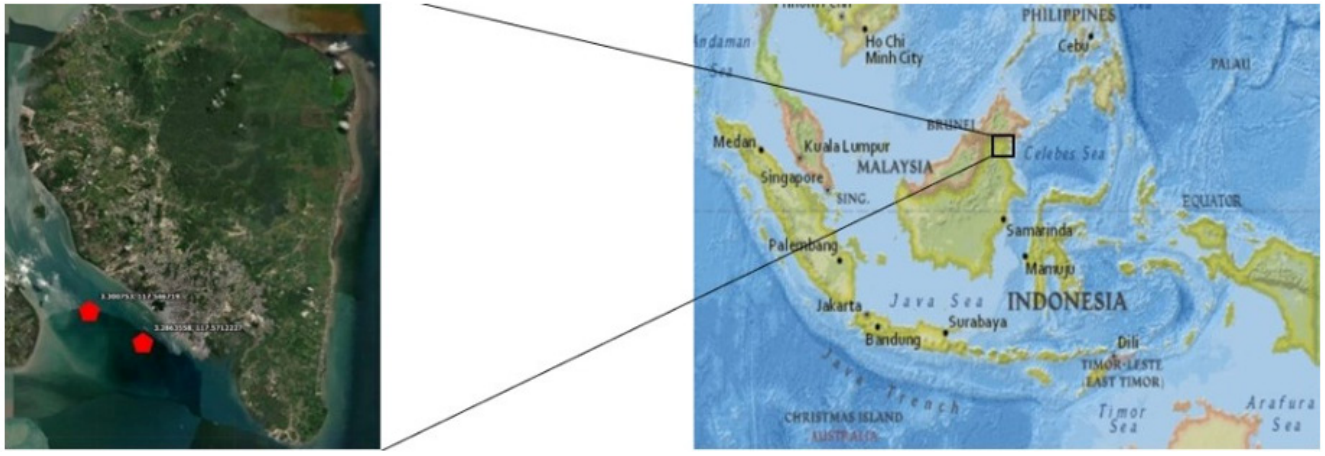

Figure 1. Map of the ecological habitat of *P. ornatus*

of Tarakan city was estimated using the following model suggested by Effendie (1979):

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

whereas:
Y = Total weight of *P. ornatus* (grams)
X = Total length of *P. ornatus* (mm)
a+b = Constant (intercept)

2.3.3. Condition Index

The condition index of the *P. ornatus* was grouped into five categories, i.e. very flat (0.01-0.50), flat (0.51-0.99), proportional/ideal (1), fat (1.01-1.50), and obese (>1.50) (Firdaus *et al.* 2020; Indarjo *et al.* 2021). Meanwhile, the allometric growth and the isometric growth and its respective condition factors were analyzed based on the methods suggested by Weatherley (1972) and Lagler (1949), respectively.

2.3.4. Absolute Growth

The absolute growth of *P. ornatus* was estimated using Von Bertalanffy's growth model, according to Sparre and Venema (1999).

2.3.5. Age Structure

The age structure of the *P. ornatus* was analyzed using the mode class shift method associated with Von Bertalanffy's growth model (Sparre and Venema 1999) by plotting the values of L(t) and ($\Delta L/\Delta t$). This linear regression equation was then used to estimate the asymptotic length ($L\infty$) and the growth coefficient (K) of *P. ornatus*. The theoretical age of the *P. ornatus* when the length is equal to zero can be estimated separately using the empirical equation suggested by Pauly (1984).

2.3.6. Mortality

The natural mortality (M) of *P .ornatus* was estimated using the empirical formula of Pauly (1984). The total mortality (Z) of *P. ornatus* was estimated using the Beverton and Holt formula (Sparre and Venema 1999). The fishing mortality (F) and the exploitation rate (E) of P.ornatus in sampling sites were estimated following Pauly (1984).

3. Results

3.1. Sex Ratio *P. ornatus*

A total of 23 lobsters were collected from the catches of bottom gill net fishermen from December 2021-July 2022, of which 12 samples were male *P. ornatus* lobsters, while the remaining 11 were female. This study showed that the male-to-female sex ratio was approximately 1.09:1, with 47.8% and 52.2%, as shown in Figure 3.

3.2. Length-Weight Relationship *P. ornatus*

From the length-weight relationship of male *P. ornatus*, the regression equation using logarithms based on the equation was y = 2/3467x-0.6132 with a determinant and correlation values of 0.8168 (81.68%) and 0.9038 (90.38%). Figure 4 shows that the regression equation for 11 female *P. ornatus* from the sample was y=2.3513x+0.3401, with a determinant and correlation value of 0.977 (97.7%)

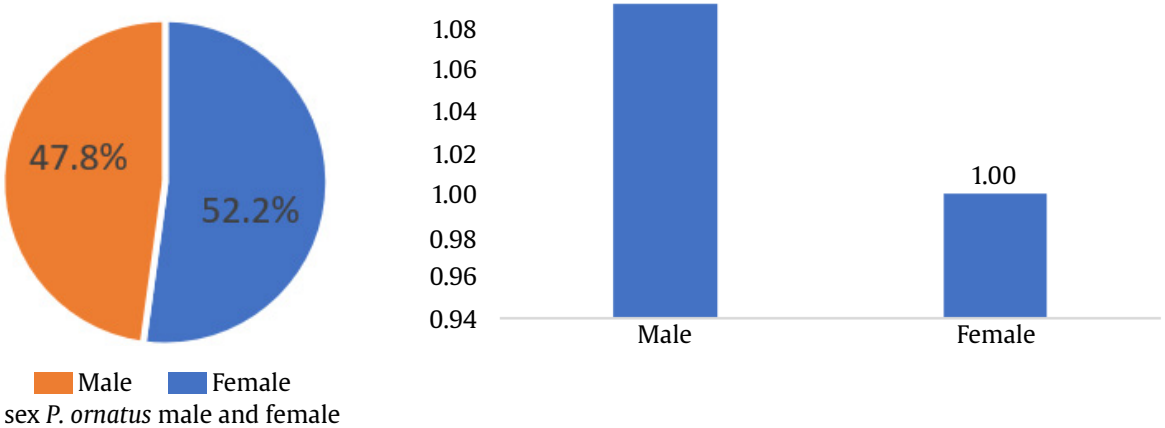

Figure 3. Ratio sex *P. ornatus* male and female

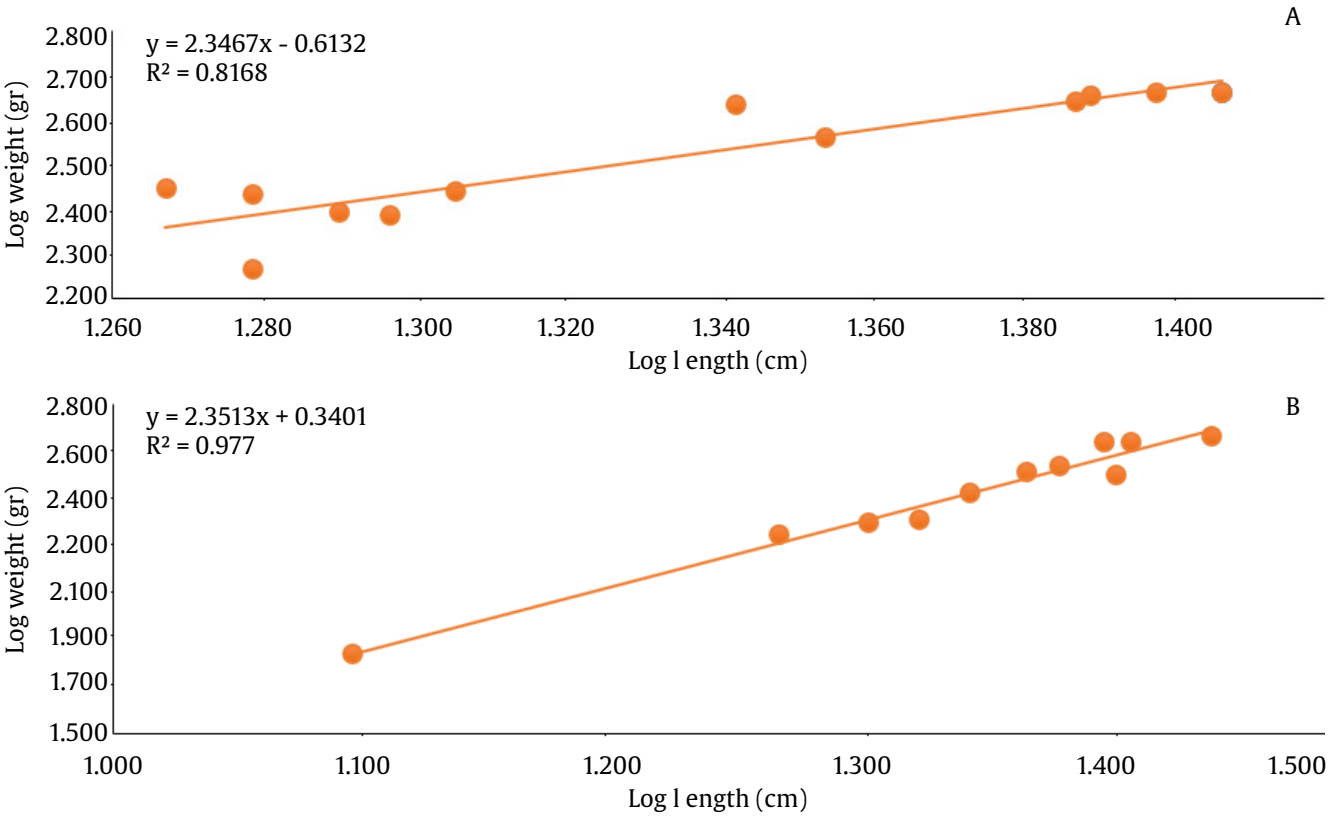

Figure 4. Length-weight relationship *P. ornatus* male (A) and female (B)

and 0.99844 (99.84%). The data is suboptimal when the determinant value is less than 0.5 (<50%). Meanwhile, it is optimal when the determinant value is more than 0.5 (>50%). A correlation value between 0.8-1.0 indicates a strong length-weight relationship.

3.3. Condition Index

The condition factor is obtained from the length and weight calculation using the regression equation method from the length-weight relationship model. Body shape criteria were obtained to determine aquatic biota's body shape value. Figure 5 shows that the criteria in the Pisces or Crustacea class are very thin, thin, proportional, fat, and very fat with condition factor values ranging from 0.01-0.50, 0.51-0.99l, 1.00, 1.01-1.50, and >1.50, respectively.

3.4. Structure Size and Absolute Growth

The length structure of male *P. ornatus* was determined by analyzing 12 individuals belonging to six distinct classes. According to Figure 6A class 1 to 6 male lobster had length structure in the range of 18.5-19.0 cm, 19.1-19.6 cm, 19.7-20.3 cm, 21.7-22.3 cm, 22.4-23.1 cm, and 24.7-25.5 cm with a percentage of 25%, 8.3%, 16.7%, 8.3%, 8.3%, and 33.3%, respectively. Based on the size structure of female lobsters, samples of around 11 individuals were collected from six classes. Furthermore, class 1, 2, 3, 4, 5, and 6 has a range of 12.5-13.4 cm, 17.2-18.5 cm, 20.1-21.7 cm, 21.8-23.5 cm, 23.6-25.4 cm, and 5.5-27.6 cm with a percentage of 9.1%, 9.1%, 18.2%, 18.2%, 27.3%, and 18.2%, respectively, as shown in Figure 6B.

The von Bertalanffy model was obtained using an orthogonal type 6 polynomial model by obtaining the age on the x-axis and the length variable (*P. ornatus*) on the y-axis. Modelled the growth of von Bertalanffy with an orthogonal type 6 polynomial model to obtain a graphic image of the growth of (*P. ornatus*) starting from the age of zero days. The orthogonal type 6 polynomial model for male lobsters regression equation is $y = -1E\text{-}12x^6 + 1E\text{-}09x^5 - 5E\text{-}07x^4 + 0.0001x^3 - 0.0131x^2 + 0.8549x + 1.5739$ with a determinant and correlation values of 0.9998 (99.98%) and 0.9999 (99.99%). Figure 7 shows the regression equation for the female orthogonal type 6 polynomial model $y = -4E\text{-}14x^6+8E\text{-}11x^5-6E\text{-}08x^4+2E\text{-}05x^3-0.0051x^2+0.5809x+1.2775$ with a determinant and correlation value of 0.9999 (99.99%) and 0.9999 (99.99%), respectively. The data is not good when the determinant value is less

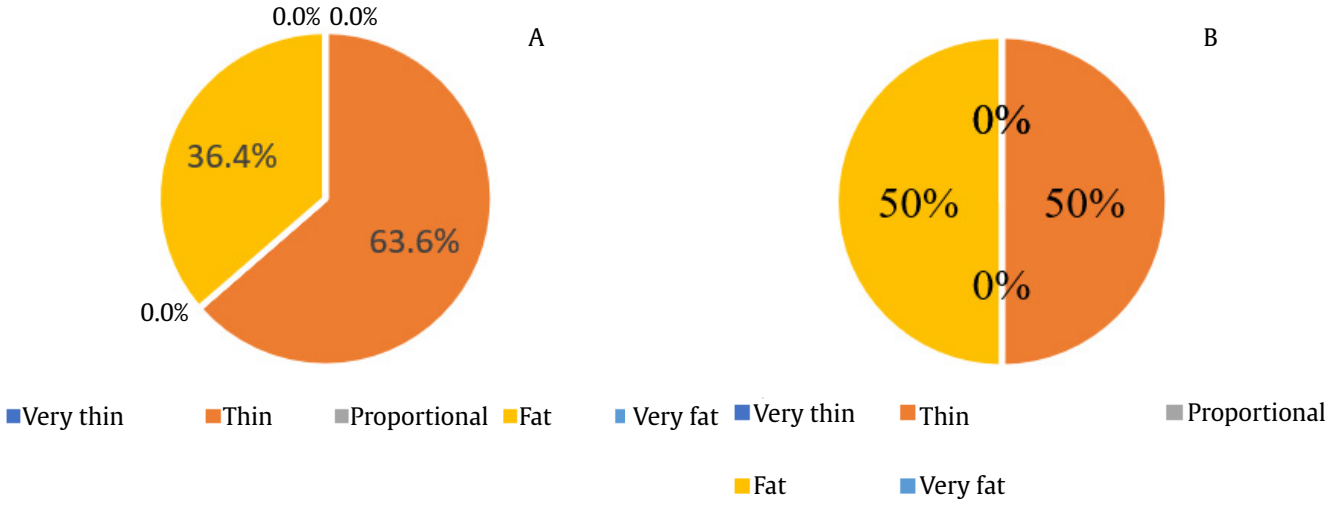

Figure 5. Condition index *P. ornatus* male (A) and female (B)

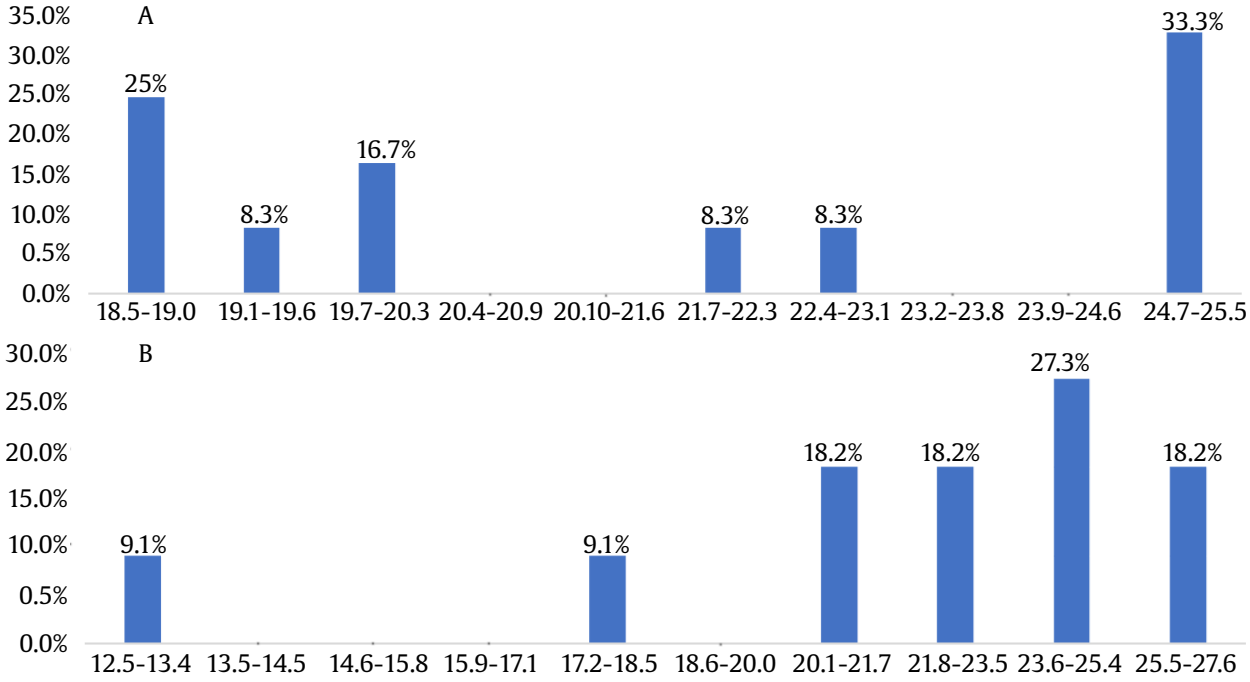

Figure 6. Structure size length *P. ornatus* male (A) and female (B)

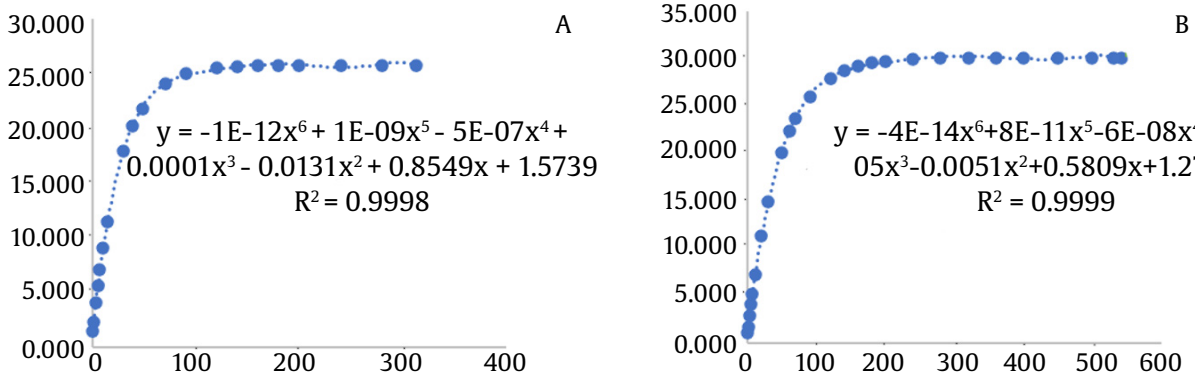

Figure 7. Model von bertalanffy *P. ornatus* male (A) and female (B)

than 0.5 (<50%). However, it is said to be good when the determinant value is more than 0.5 (>50%). The correlation value ranged between 0.8-1.0, indicating a strong length-weight relationship variable.

3.5. Mortality

The data processing using the *P. ornatus* resulted in a total sample of 23 individuals. The total mortality value for males and females were 109.1% greater and 105.1%, respectively. Male *P. ornatus* lobsters had a mortality rate of 35.6%, higher than females of 3.7%. This follows their exploitation rate of 32.7%, higher than females at 3.5%. However, the natural mortality in female lobsters at 101.4% was higher than in males at 73.5%, as presented in Figure 8.

3.6. Ecological Habitat *P. ornatus*

Based on the ecology of the *P. ornatus* habitat where measurements of water quality in the western part of the waters of the city of Tarakan, were obtained ecological preference variables were obtained in the form of dissolved oxygen, temperature, salinity, pH, electrical conductivity, depth, and brightness with values of 7.3-7.4 mg/L, 26.9 27.4°C, 26-27 ppt, 7.35-7.42, 23.67-24.22 mhos/cm, 12-20 m and 1.75-2.3 m, respectively (Figure 9).

4. Discussion

The sex ratio research explained that the male *P. ornatus* was more dominant than the females in the waters of Sebatik, North Kalimantan. Priyambodo *et al.* (2020) reported that the lowest and highest catch seasons were from December to March and April to November, respectively. Research by Foo (2020) and Muzammil and Kurniadi (2020) reported an imbalance sex ratio between males and females. According to Mendes *et al.* (2016), the asymptotic growth of the lobster carapace was inversely correlated with the growth rate.

Sparee and Venema (1999); Salim *et al.* (2021); Indarjo *et al.* (2021) stated that the regression equation described the relationship between the total length of male or female lobsters on the x-axis and the growth rate on the y-axis. Salim *et al.* (2020), (2021) set up the regression equation in the Von Bertalanffy growth model to obtain asymptotic growth. According to Figure 7, the asymptotic growth

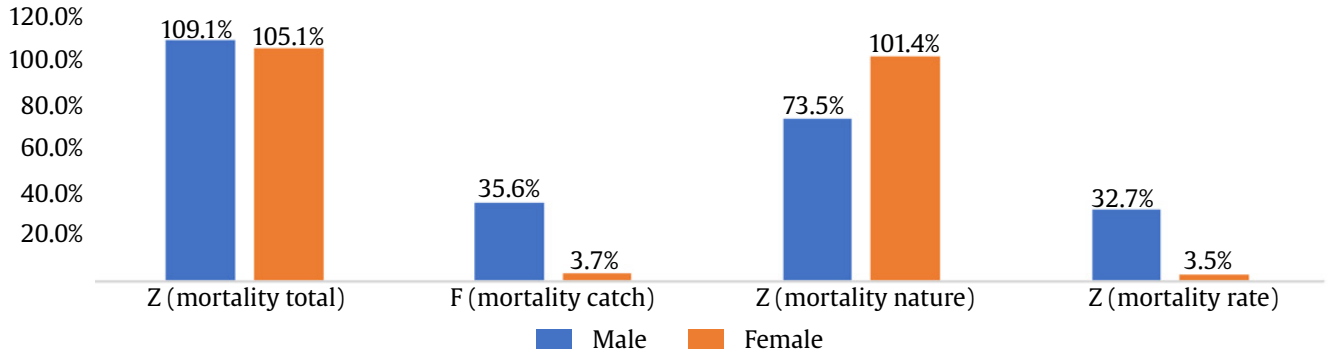

Figure 8. Mortality *P. ornatus* male and female

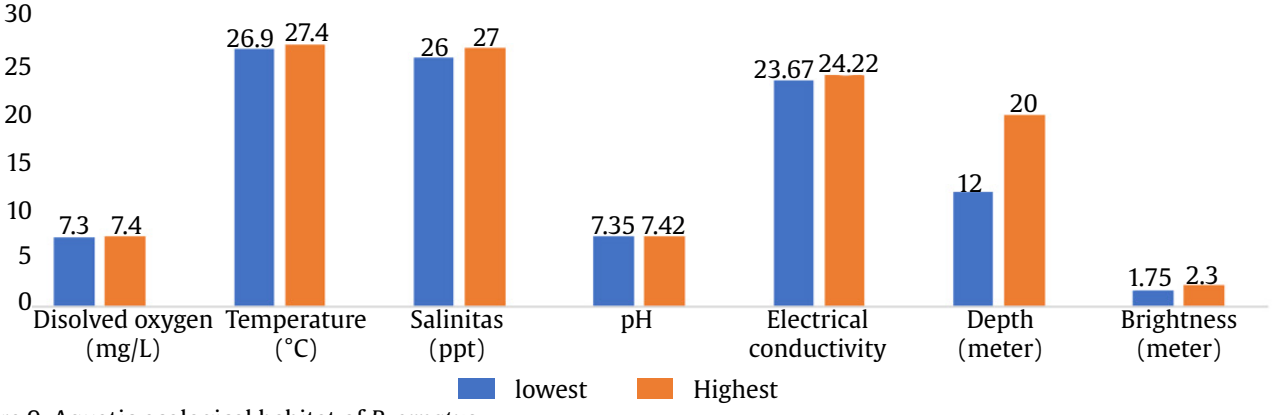

Figure 9. Aquatic ecological habitat of *P. ornatus*

is obtained when the regression line meets the x-axis. In the make lobsters, regression equation, y = -0.378x + 0.9733 with determinant and correlation values of 0.6547 (65.47%) and 0.8996 (89.96%). Meanwhile, the female lobster regression equation obtained y = -0.0216x + 0.6505 with determinant and correlation values of 0.819 (81.9%) and 0.9352 (93.52%). Pakpahan *et al.* (2022) stated that the data is not good when the determinant value is less than 0.5 (<50%). However, it is said to be good when the determinant value is more than 0.5 (>50%). Pakpahan *et al.* (2022) explained that the correlation value between 0.8-1.0 indicates a strong length-weight relationship.

Chang *et al.* (2012) stated that the size determination at a certain age of recruitment could be used to obtain a Von Bertalanffy model for sustainable fisheries management. However, Nguyen *et al.* (2018) considered the need to integrate growth discontinuities. This is because the development of *P. ornatus* lobsters is influenced by the periodical shedding of the old exoskeleton. Chang *et al.* (2012) reported that the moulting cycle could not be estimated, making it challenging to determine growth at some point. According to Talbot *et al.* (2018), the growth effect is affected by environmental factors and food availability in *P. ornatus*. Vicenzi *et al.* (2014) reported that environmental variability could influence development. However, individual variability has not been thoroughly discussed to obtain the maximum length growth rate (asymptotic). Growth can be estimated when considerable heterogeneity between individuals is persistently disregarded. Therefore, modelling the process while considering environmental and individual variability in *P. ornatus* lobster is required.

The infinitive growth in males and females is 25.749 cm and 30.116 cm in 313 days and 542 days, respectively. Based on the male and female Von Bertalanffy *P. ornatus* model, the growth rate of infinitive length can be influenced by individual factors, such as gender. The female and male sex reached an asymptotic length in 542 and 313 days, respectively. This is consistent with the report by Foo (2020), which stated that the estimated growth parameters are determined by gender, with the deviation in the growth rate being higher in female lobsters. During maturation, the female gonads require sufficient energy to attain their asymptotic length. In Figure 8, the male and female sexes of *P. ornatus* exhibit an increasing pattern, resulting in infinite growth.

Furthermore, the growth of the female species has a higher rate and asymptotic length than the male. The first length catch (Lc) of male and female *P. ornatus* was 21.7 cm and 22.3 cm. Using the Von Bertalanffy model shown in Figure 8, the age at the first length catch (Lc) was 48 and 61 days. According to Muzammil and Kurniadi (2020), research on *P. ornatus* at Sebatik reached the first catch length (Lc) of 7.128 cm. Kusnok *et al.* (2014) and Liu *et al.* (2014) stated that the first length catch (Lc) could be determined when 50% of the population has been caught, with fish catch pressure (Kusnok *et al.* 2014) and fishing gear type being the influencing factors (Liu *et al.* 2014). However, the male and female fish caught were 24.7-25.5 cm and 23.6-25.4 cm in length.

The catch mortality of male (35.6%) and female (3.7%) *P. ornatus* was higher than their exploitation rate at 32.7% and 3.5%. Furthermore, Priyambodo explained that the presence of different periodic moons affects the catch. According to Priyambodo *et al.* (2017), the influencing factor was due to the positive phototaxis of the lobster and the natural mortality, which is very high compared to the catch mortality. Natural mortality is presumed to be caused by disease/virus or food chain factors. However, environmental parameters are not considered to be natural causes of death. Ecological preference variables were obtained in the form of dissolved oxygen, temperature, salinity, pH, electrical conductivity, depth, and brightness with values of 7.3-7.4 mg/L, 26.9 27.4°C, 26-27 ppt, 7.35-7.42, 23.67-24.22 mhos/cm, 12-20 m and 17.5-2.3 m, respectively. Nurfiarini *et al.* (2016) reported that salinity has a role in biological processes and growth rates in the amount of food consumed. Temperatures between 11-29°C and dissolved oxygen support the life of juvenile lobsters (Milton *et al.* 2014), and brightness affects the growth rate because the ecology is slightly cloudy (Milton *et al.* 2014). Milton *et al.* (2014) stated that the ecological dynamics for juvenile lobsters tend to be in sandy and rocky habitats overgrown with seagrass algae (Sargassum) at a depth of 5-10 meters and associated with tabulate/encrusting/massive corals. According to Wahyudin *et al.* (2016), the ecology of *P. ornatus* is discovered at a depth of 1-10 m. They

can also be identified at 200 m deep, inhabiting coral reefs with calm currents or muddy substrates at river mouths having cloudy conditions. Jones *et al.* (2019) stated that the optimal temperature for *P. ornatus* is approximately 25-28°C, with a salinity tolerance of 25-35 ppt. Tropical species *P. ornatus* and *P. homarus* in Indonesia and Vietnam have the highest abundance in the coastal areas. These species have high turbidity and salinity gradient of <33 ppt influenced by tidal currents from the ocean waters (Piyambodo 2015, 2015b, 2015c; Anh and Jones 2015).

In conclusion, the size of the male *P. ornatus* was more significant than the female. It was discovered in this study that the growth of *P. ornatus* was negative allometric for both genders and the condition index recorded both fat and thin individuals. The von Bertalanffy growth model of the male was slower than the female. However, the male reached faster asymptotic growth than the female. Male *P. ornatus* had a greater total mortality rate than females. However, it was primarily due to capture fishery and exploitation. Meanwhile, its natural mortality rate was lower than that of females, indicating a higher male exploitation rate. It can be concluded from these results that the management of *P. ornatus* in the waters of West Tarakan needs to be further improved through the utilization of better domestication and restocking techniques to reach an optimal sustainability level. Research on the reproduction of the lobster P. ornatus and its domestication is recommended since it is crucial in maintaining and protecting the Lobster *P. ornatus* in the waters west of the city of Tarakan so that it remains sustainable.

Acknowledgements

The author would like to thank the Institute of Service (LPPM) of the University of Borneo Tarakan (UBT).

References

Anh, T.L., Jones, C., 2015. Status report of Vietnam lobster grow-out, chapter 4.2, in: Jones, C.M. (Eds.), *Spiny Lobster Aquaculture Development in Indonesia, Vietnam and Australia: Proceedings of the International Lobster Aquaculture Symposium Held in Lombok, Indonesia, 22–25 April 2014*. Australian Centre for International Agricultural Research, Canberra, pp. 82–86.

Anh, T.L., Jones, C., 2015a. Lobster seed fishing, handling and transport in Vietnam, chapter 2.4, in: Jones, C.M. (Eds.), *Spiny lobster aquaculture development in Indonesia, Vietnam and Australia: Proceedings of the International Lobster Aquaculture Symposium held in Lombok, Indonesia, 22–25 April 2014*. Australian Centre for International Agricultural Research, Canberra, pp. 31–35.

Andrykusuma, D.H.P., Redjeki, S., Riniatsih, I., 2022. Laju pertumbuhan harian dan nisbah kelamin lobster pasir *Panulirus homarus* di Perairan Liwungan, Pandeglang, Banten. *Journal of Marine Research*. 11, 86-91.. https://doi.org/10.14710/jmr.v11i1.31248

Bahrawi, S., Priyambodo, B., Jones, C., 2015a. Assessment and development of the lobster seed fishery of Indonesia, chapter 2.3, in: Jones, C.M. (Eds.), *Spiny Lobster Aquaculture Development in Indonesia, Vietnam and Australia: Proceedings of the International Lobster Aquaculture Symposium Held in Lombok, Indonesia, 22–25 April 2014. Australian Centre for International Agricultural Research*, Canberra, pp. 27–30.

Bahrawi, S., Priyambodo, B., Jones, C., 2015b. Lobster seed fishing, handling and transport in Indonesia, chapter 2.5, in: Jones, C.M. (Eds.), *Spiny Lobster Aquaculture Development in Indonesia, Vietnam and Australia: Proceedings of the International Lobster Aquaculture Symposium Held in Lombok, Indonesia, 22–25 April 2014*. Australian Centre for International Agricultural Research, Canberra, pp. 36–38.

Chang, Y.J., Sun, C.L., Chen, Y., Yeh, S.Z., 2012. Modelling the growth of crustacean species. *Rev. Fish. Biol. Fish.* 22, 157–187. https://doi.org/10.1007/s11160-011-9228-4

Chodrijah, U., Priatna, A., Nugroho, D., 2018. Distribusi ukuran panjang dan parametr populasi lobster lumpur (*Panulirus polyphagus* Herbst, 1793) di Perairan Sebatik, Kalimantan Utara (WPPNRI-716), *J. Penelit. Perikan. Indones.* 24, 11-23. https://doi.org/10.15578/jppi.1.1.2018.11-23

Dao, H.T., Jones, C., 2015. Census of the lobster seed fishery of Vietnam, chapter 2.2, in: Jones, C.M. (Eds.), *Spiny Lobster Aquaculture Development in Indonesia, Vietnam and Australia: Proceedings of the International Lobster Aquaculture Symposium Held in Lombok, Indonesia, 22–25 April 2014*. ACIAR Proceedings, Canberra, pp. 21–26.

Dao, H.T., Smith-Keune, C., Wolanski, E., Jones, C.M., Jerry, D.R., 2015. Oceanographic currents and local ecological knowledge indicate, and genetics does not refute, a contemporary pattern of larval dispersal for the ornate spiny lobster, *Panulirus ornatus* in the south-east Asian archipelago. *PLoS One* 10, e0124568. https://doi.org/10.1371/journal.pone.0124568

Effendie, M.I., 2002. *Biologi Perikanan*. In Yayasan Pustaka Nusatama, Yogyakarta.

Effendie, M., 1979. *Metode Biologi Perikanan*. Yayasan Dewi Sri, Bogor.

Firdaus, M., Salim, G., Cahyadi, J., Weliyadi, E., Bintoro, G., 2020. Model and nature of growth of red snapper fish (*Lutjanus argentimaculatus* (Forsskål, 1775) fishing catch of bottom fish pots in Bunyu waters, North Kalimantan. *AACL Bioflux*. 13, 1410-1421.

Foo, C.H., 2020. Parameter estimation of laboratory reared *Panulirus ornatus*. *SN Applied Sciences*. 2, 805. https://doi.org/10.1007/s42452-020-2612-8

Garibaldi, L., 2012. The FAO global capture production database: a six-decade effort to catch the trend. *Marine Policy*. 36, 760-768. https://doi.org/10.1016/j.marpol.2011.10.024

Idris, M., Bahrawi, S., 2015. Assessment of tropical spiny lobster aquaculture development in South Sulawesi, Indonesia, vhapter 5.11, in: Jones, C.M. (Eds.), *Spiny Lobster Aquaculture Development in Indonesia, Vietnam and Australia: Proceedings of the International Lobster Aquaculture Symposium Held in Lombok, Indonesia, 22–25 April 2014*. Australian Centre for International Agricultural Research, Canberra, pp. 148–149.

Indarjo, A., Salim, G., Zein, M., Septian, D., Bija, S. 2020. The population and mortality characteristics of mangrove crab (*Scylla serrata*) in the mangrove ecosystem of Tarakan City, Indonesia. *Biodiversitas Journal of Biological Diversity*. 21, 3856-3866. https://doi.org/10.13057/biodiv/d210855

Indarjo, A., Salim, G., Nugraeni, C.D., Zein, M., Ransangan, J., Prakoso, L.Y., Suhirwan, Anggoro, S., 2021. Length-weight relationship, sex ratio, mortality and growth condition of natural stock of *Macrobrachium rosenbergii* from the estuarine systems of North Kalimantan, Indonesia. *Biodiversitas.* 22, 846-857. https://doi.org/10.13057/biodiv/d220239

Jones, C.M., Anh, T.L., Priyambodo, B., 2019. Lobster aquaculture development in Vietnam and Indonesia, in: Radhakrishnan, E.V., Phillips, B.F., Achamveetil, Gopalakrishnan, (Eds.), *Lobsters: Biology, Fisheries and Aquaculture*. Springer Nature Singapore Pte Ltd, Singapore, pp. 541–570. https://doi.org/10.1007/978-981-32-9094-5_12

Kunsook, C., Gajaseni, N., Paphavasit, N., 2014. A stock assessment of the blue swimming crab *Portunus pelagicus* (Linnaeus, 1758) for sustainable management in Kung Krabaen Bay, Gulf of Thailand. *Tropical Life Sciences Research*. 25, 41-59.

Lagler, KF., 1949. Studies in freshwater fishery biology: a review. *Copeia.* 1949, 82–82. https://doi.org/10.2307/1437683

Liu Z, X., Wu, W., Wang, B., Yan, Y., Cheng, 2014. Size distribution and monthly variation of ovarian development for the female blue swimmer crab, *Portunus pelagicus* in Beibu Gulf, of South China. *Scientia Marina*. 78, 257-268. https://doi.org/10.3989/scimar.03919.24A

Muzammil, W., Bambang Kurniadi, 2020. Carapace length-frequency distribution and carapace length-weight correlation of ornate spiny lobster (*Panulirus ornatus*) in Sebatik Island Waters–Indonesia. *E3S Web of Conferences.* 324, 03009. https://doi.org/10.1051/e3sconf/202132403009

Mendes-Junior, R.N.G., Sá-Oliveira, J.C., Ferrari, S.F., 2016. Biology of the electric eel, *Electrophorus electricus,* Linnaeus, 1766 (Gymnotiformes:Gymnotidae) on the floodplain of the Curiaú River, eastern Amazonia. *Rev. Fish. Biol. Fish.* 26, 83–91. https://doi.org/10.1007/s11160-015-9407-9

Milton, D.A. Satria, F., Proctor, C.H., Prasetyo, A.P., Utama, A.A., Fauzi, M., 2014. Environmental factors influencing the recruitment and catch of tropical *Panulirus lobsters* in southern Java, Indonesia. *Continental Shelf Research*. 91, 247-255. https://doi.org/10.1016/j.csr.2014.09.011

Ng, W.L., Chen, C.A., Mustafa, S., Leaw, C.P., Teng, S.T., Zakaria S.N.F.B., Tuzan, A.D., Chan, T.Y., 2022. A new record of the spiny lobster, *Panulirus femoristriga* (von Martens, 1872) from the coastal waters of Malaysia, with revision of global distribution. *Biodiversity Data Journal*. 10, e77973. https://doi.org/10.3897/BDJ.10.e77973

Nguyen, T.V., Jung, H., Rotlant, G., Hurwood, D., Mather, P., Ventura, T., 2018. Guidelines for RNA-seq projects: applications and opportunities in non-model decapod crustacean species. *Hydrobiologia*. 825, 5-27. https://doi.org/10.1007/s10750-018-3682-0

Nurfiarini, Danu Wijaya, Mujiyanto, Fayakun Satria, Endi Setiadi Kartamihardja, 2016. Socio-ecological approach to valuing restocking location feasibility ff *Panulirus homarus* (Linnaeus, 1758) in some water in Indonesia. *Jurnal Perikanan Penelitian Indonesia*. 22, 123-138. http://doi.org/10.15578/jppi.22.2.2016.123-138

Pakpahan, M., Amruddin Amruddin, Riama Marlyn Sihombing, Valentine Siagian, Sony Kuswandi, Rohayati Arifin, Mukhoirotin Mukhoirotin, Karwanto Karwanto, Isnada Waris Tasrim, Iskandar Kato, Hani Subakti, Novita Aswan, 2022. *Metodologi Penelitian*. Cendekia Publisher, Medan.

Pauly, D., 1984. Fish population dynamics in tropical waters: a manual for use with programmable calculators. *International Center for Living Aquatic Resources Management. Part B. Biological Sciences*. 33, 252-279.

Priyambodo, B., 2015a. Development of the lobster farming industry in Indonesia, chapter 5.5, in: Jones, C.M. (Eds.), *Spiny Lobster Aquaculture Development in Indonesia, Vietnam and Australia: Proceedings of the International Lobster Aquaculture Symposium Held in Lombok, Indonesia, 22–25 April 2014.* Australian Centre for International Agricultural Research, Canberra, pp. 114–118.

Priyambodo, B., 2015b. Development of the lobster farming industry in Indonesia, in: Jones, C. (Eds.), *Spiny lobster aquaculture development in Indonesia, Vietnam and Australia: Proceedings of the International Lobster Aquaculture Symposium held in Lombok, Indonesia, 22–25 April 2014*. Australian Centre for International Agricultural Research, Canberra, pp. 114-118.

Priyambodo, B., 2015c. Study tour of Indonesian farmers to Vietnam lobster aquaculture industry in 2013, chapter 5.8, in: Jones, C.M. (Eds.), *Spiny Lobster Aquaculture Development in Indonesia, Vietnam and Australia. Proceedings of the International Lobster Aquaculture Symposium Held in Lombok, Indonesia, 22–25 April 2014*. Australian Centre for International Agricultural Research, Canberra, 136–141.

Priyambodo, B., Jones, C., Sammut, J., 2015. The effect of trap type and water depth on puerulus settlement in the spiny lobster aquaculture industry in Indonesia. *Aquaculture.* 442, 132–137. https://doi.org/10.1016/j.aquaculture.2015.02.037

Priyambodo, B., Jones, C.M., Sammut, J., 2017. Improved collector design for the capture of tropical spiny lobster, *Panulirus homarus* and *P. ornatus* (Decapoda: Palinuridae), pueruli in Lombok, Indonesia. *Aquaculture.* 479, 321–332. https://doi.org/10.1016/j.aquaculture.2017.05.033

Priyambodo, B. Jones, C.M., Sammut, J., 2020. Assessment of the lobster puerulus (*Panulirus homarus* and *Panulirus ornatus*, Decapoda: Palinuridae) resource of Indonesia and its potential for sustainable harvest for aquaculture. *Aquaculture.* 528, 735563. https://doi.org/10.1016/j.aquaculture.2020.735563

Saputra, W.A., Pambudi, K.A., Setyanto, A., Tumulyadi, A., 2020. The differences of depth on the species composition of spiny lobster puerulus on south. *Pacitan Regency East Java. IOP Conf. Ser.: Earth and Environmental Science*. 441, 012130. http://doi.org/10.1088/1755-1315/441/1/012130

Salim, G., Handayani, K.R., Anggoro, S., Indarjo, A., Syakti, A.D., Ibrahim, A.J., Ransangan, J., Prakoso, L.Y., 2020. Morphometric analysis of *Harpodon nehereus, Harpiosquilla raphidea*, and *Scylla serrata* in the coastal waters of Tarakan, North Kalimantan, Indonesia. *Biodiversitas*, 21, 4829-4838. https://doi.org/10.13057/biodiv/d211049

Salim, G., Handayani, K.R., Indarjo, A., Ransangan, J., Rizky, R., Prakoso, L.Y., Pham, Y.T.H., 2021. Characteristics of population growth and mortality of windu shrimp (*Penaeus monodon*) in the Juata Water of Tarakan City, Indonesia. *Jurnal Ilmiah Perikanan dan Kelautan.* 13, 114-120. http://doi.org/10.20473/jipk.v13i1.21475

Setyanto, A., Rachman, N.A., Yulianto, E.S., 2018. Distribusi dan komposisi spesies lobster yang tertangkap di Perairan Laut Jawa bagian Jawa Timur, Indonesia. *J. Perikan. Univ. Gadjah Mada.* 20, 49-55. http://doi.org/10.22146/jfs/.36151

Setyanto, Halimah, 2019. Biodiversitas lobster di Teluk Prigi, Trenggalek Jawa Timur. *Journal of Fisheries And Marine Research*. 3, 344-349. http://doi.org/10.21776/ub.jfmr.2019.003.03.9

Setyanto, A, Soemarno, D.G.R., Wiadnya, Cahyo Nugroho, 2019. Biodiversity of lobster (*Panulirus*) from Eastern Indian Ocean of Indonesia Waters. *IOP Conf. Series: Materials Science and Engineering.* 546, 022024. http://doi.org/1.0.1088/1757-899X/546/2/022024

Setyanto A., Saputra, W.A., Pambudi, K.A., Tumulyadi, A., 2020. The differences of depth on the species composition of Spiny Lobster Puerulus on South Pacitan Regency, East Java. *E3S Web of Conferences.* 153, 01008. http://doi.org/10.1051/e3sconf/202015301008.

Setyanto, 2020. Species composition of puerulus spiny lobsters from the South Sea of Pacitan of East Java, Indonesia. *IOP Conf. Ser. Earth Environ. Sci.* 493, 012022. http://doi.org/10.1088/1755-1315/493/1/012022

Setyanto, A., Sambah, B., Widhiastika, D., Soemarno, D.G.R., Wiadnya, Prayogo, C., 2021. Population structure and biological aspects of lobster (*Panulirus* spp.) of the Madura Strait landed in Situbondo of East Java, Indonesia. *IOP Conf. Series: Earth and Environmental Science.* 919, 012015. http://doi.org/10.1088/1755-1315/919/1/012015

Sparre, P., Venema, S.C., 1999. *Introduksi Pengkajian Stok Ikan Tropis*. Pusat Penelitian dan Pengembangan Perikanan, Badan Penelitian dan Pengembangan Pertanian, Jakarta.

Sukamto, Muryanto, T., Kusiani, H., 2017. Teknik identifikasi jenis kelamin lobster bebasis ciri-ciri morfologi. *Buletin Teknik Litkayasa.* 15, 99-102. http://doi.org/10.15578/btl.15.2.2017.99-102

Talbot, S.E., Widdicombe, S., Hauton, C., Bruggeman, J., 2018. Adapting the dynamic energy budget (DEB) approach to include non-continuous growth (moulting) and provide better predictions of biological performance in crustaceans. *ICES J Mar Sci.* 76, 192–205. https://doi.org/10.1093/icesjms/fsy164

Utomo, P.B.N., Sulistiono, Affandi, R., Nugroho, T., Murhum, M., Manan, H., 2018. Penampungan lobster (*Panulirus* spp.) dalam rangka pemberdayaan masyarakat di Pulau Gebe, Halmahera Tengah, Maluku Utara (Stocking of Lobster (*Panulirus* spp). *Agrokreatif Jurnal Ilmiah Pengabdian kepada Masyarakat*. 4, 81-91. https://doi.org/10.29244/agrokreatif.4.2.81-91

Vincenzi, S., Mangel, M., Crivelli, A.J., Munch, S., Skaug, H.J., 2014. Determining individual variation in growth and its implication for life-history and population processes using the empirical Bayes method. *PLoS Comput Biol* 10, e1003828. https://doi.org/10.1371/journal.pcbi.1003828

Wahyudin, R.A., Hakim, A.A., Boer, M., Farajallah, A., Wardiatno, Y., 2016. New records of *Panulirus femoristriga* Von Martens, 1872 (crustacea achelata palinuridae) from Celebes and Seram Islands, *Indonesia Biodiversity Journal*. 7, 901-906.

Wahyudin, R.A.,Wardiatno, Y., Boer, M., Farajallah, A., Hakim, A.A., 2017a. A new distribution record of the mud-spiny lobster, *Panulirus polyphagus* (Herbst, 1793) (Crustacea, Achelata, Palinuridae) in Mayalibit Bay, West Papua, Indonesia. *Biodiversitas*. 18, 780-783. http://doi.org/10.13057/biodiv/d180248

Wahyudin, R.A., Hakim, A.A., Qonita, Y., Boer, M., Farajallah A., Mashar, A., Wardiatno, Y., 2017b. Lobster diversity of Palabuhanratu Bay, South Java, Indonesia with new distribution record of *Panulirus ornatus, P. polyphagus* and *Parribacus antarcticus. AACL Bioflux*. 10, 308-327.

Weatherley, A.H., 1972. *Growth and Ecology of Fish Population.* Academic Press, New York.

Wardiatno, Y., Hakim, A., Mashar, A., Butet, N., Adrianto, L., Farajallah, A., 2016. First record of *Puerulus mesodontus* Chan, Ma and Chu, 2013 (*Crustacea, Decapoda, Achelata, Palinuridae*) from south of Java, Indonesia. *Biodiversity Data Journal.* 4, e8069. http://doi.org/ 10.3897/BDJ.4.e8069