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Age Structure, Growth, and Mortality of Blue Swimming Crab (*Portunus pelagicus* Linnaeus,1758) in Banten Bay Waters

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Abstract. *Blue swimming crab (BSC) (Portunus pelagicus) is the main fisheries commodity in Banten Bay, with the highest catch of catch occurring in the west monsoon. Increased fishing efforts have reduced the catch, as indicated by a decrease in the average size of carapace width. Overfishing might influence the life cycle and population structure of the BSC. This research aims to analyze the growth and mortality of the Blue Swimming Crab in Banten Bay, especially in the west monsoon. Blue swimming crab samples were obtained from the catch of fish trap and gillnet fishermen with landing sites around the Karangantu Archipelago Fishing Port. Growth, age, and mortality were predicted based on the measurement of total carapace width and body weight. Data were analyzed using Fisat II and Microsoft Excel. The frequency distribution of carapace showed one mode class which normally was distributed consisting of only one age structure group (cohort). The relationship between carapace width and weight of males or females resulted in a slope value (b>3) and was positive allometric, indicating that both sexes had a faster weight gain than the increase in carapace width. Growth parameters resulted asymptotic length (L∞); male 176.75 mm and female 176.46 mm. The growth was relatively fast, with a growth coefficient value of more than one. The mortality showed that the fishing mortality value (F);in males was 3.47 /year and in females 2.69/year was greater than the natural mortality value (M); males 1.25/year and females 1.22/year. Blue Swimming Crabs in Banten Bay had overfished as shown by the high fishing mortality value and there were still many BSC that were caught below the legal size allowed. Thus, catches should be controlled to keep the population and for sustainable fisheries.*

Keywords: *Carapace, fisheries, Karangantu, positive allometric*

Citation
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INTRODUCTION

Blue Swimming Crab (BSC) (*Portunus pelagicus*) included in the crustacean class, which fully lives in the sea. It has a wide and flat carapace and has a rough texture. BSC is a demersal animal, many found in the tidal zone up to 50 m water depth (Safaie et al., 2013; Wulandari et al., 2014; Asphama et al., 2020). BSC is one of Indonesia's most economically important fishery species and the third largest export fishery commodity after tuna and shrimp (Hutapea et al., 2019; Sara et al., 2019; Nurdin et al., 2022). Based on the assessment of production value, selling price, marketing area, and added value, Blue Swimming Crab is the main fisheries commodity in Banten Bay Waters (Ernaningsih, 2012).

Banten Bay waters, part of the Republic of Indonesia Fisheries Management Area (WPP RI) 712, this management area was the largest proportion of production compared to other water areas and showed to increase in production volume from year to year (MMAF 2020). The problem in this area is that crab resources were limited crabs due to the increased crab fishing effort (Budiarto, 2015). Decreasing BSC of carapace width average has already occurred in Banten Bay waters (Susanto et al., 2019). Decreasing carapace width average signed that occurred of overfishing will affect the population in the future and this phenomenon can be seen from a large number of BSC catches that were below the legal size from regulation of the Minister of marine affairs fisheries number 16 of 2022 (Ernawati et al., 2015).

The BSC fisheries in Banten Bay are classified as small-scale with fishing vessels < 5 GT, using trap and gillnets as main fishing gear (Susanto et al., 2019). The peak season for BSC catch is during the West Monsoon when winds move from the Asian Continent (winter) to the Australian Continent (summer) and contain high rainfall. This wind blows from December - January (Solihuddin, 2020). Generally, the catching season for BSC in Banten Bay occurs throughout the year. The peak season is in December–February, the medium season is in September–October and the fall season is in March–August (Sari, 2012).

Growth and mortality parameters are closely related to the condition of a population. Growth parameters predict age and growth rates while mortality results in a decrease in stock size and loss of regeneration opportunities. Variations in growth parameters and mortality are thought to be related to differences in habitat conditions, temperature, salinity, oxygen, brightness, and fishing intensity (Hamid, 2015). A Previous study on BSC in Banten Bay by Diskibiony (2012) showed a nature of positive allometric growth and natural mortality value was greater than fishing mortality. However, this study used limited data obtained outside the west monsoon. Research conducted by Fauzi et al. (2018) on the assessment of crab's growth overfishing in Banten Bay showed the nature of positive allometric growth, with the male population decreased, growth overfishing occurs when a catch is dominated by small crabs. This study did not explain other growth parameters such as asymptotic length and growth coefficient. Therefore, this study aimed to determine the growth and mortality parameters of BSC in the west monsoon as the peak season for BSC in Banten Bay based on the length frequency data. The results of this study are expected to be used as consideration for sustainable management of BSC fisheries in Banten Bay waters.

MATERIALS AND METHODS

Study Site

The research was conducted from December 2021 to February 2022 in Karangantu Archipelago Fishing Port, Serang City, Banten Province (Figure 1).

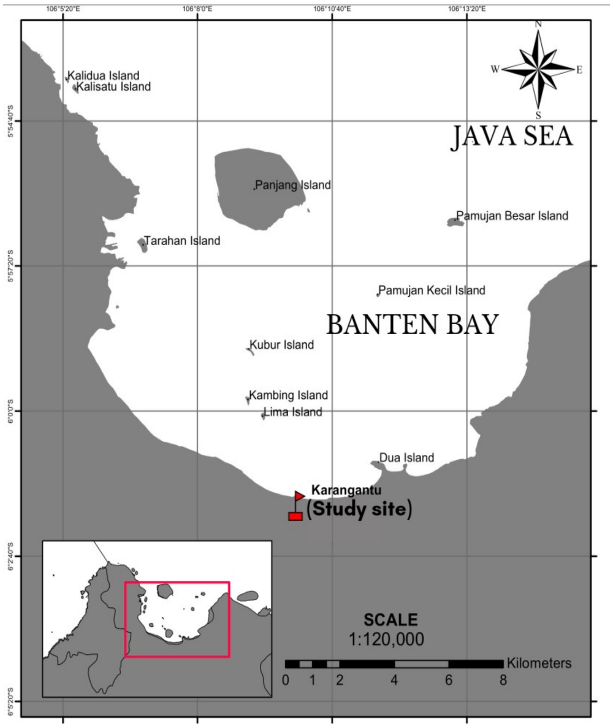

Figure 1. Study site in Karangantu Archipelago Fishing Port

Data Collection

A Samples of BSC were obtained from the fisherman's catch of gillnets and fish trap (bubu) located around Karangantu Archipelago Fishing Port. The fishermen's gillnets and fish trap (bubu) operated in the waters of Banten Bay for a duration of one-day fishing. Data collection was carried out every day for three months. Samples were collected by random sampling and stored in one basket. The total samples measured were 4,448 for males and 2,796 for females. Samples that have been taken were measured for carapace width, weight, and sex determination. Carapace width was determined by measuring the distance between the longest spines on both sides using a ruler with an accuracy of 0.1 mm. Body weight was weighed using a digital scale with an accuracy of 0.001 g. To determine the sex of crabs by looking at carapace color and abdominal shape. Carapace color was observed based on spots, where female BSC is patterned with brown spots, while male BSC has blue spots and the shape of the male BSC abdomen is pointed and does not bag the eggs, while female BSC is curved and bag the eggs (Sunarto, 2012; Abrenica et al., 2021).

Data Analysis

Age Structure

Analysis of age structure was conducted using a formula/method as Bhattacharya (1967) proposed by splitting overall frequency data of carapace width into several normal distributions of carapace width frequency distribution. Each new normal distribution represents one age group (cohort) (Sparre & Venema, 1999).

Growth Parameters

Analysis of the relationship between carapace width (L) and weight (W) fitted using power mode regression for male and female

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BSC separately proposed by Ricker (1973) (Ernawati et al., 2017). The growth parameters curve followed the *von Bertalanffy* equation (Ernawati et al., 2015). Growth analysis of infinite carapace width (L∞) and growth rate (K) was calculated using the ELEFAN package in FISAT II (Gayanilo et al., 2005). The infinite carapace width (L∞) can also be estimated using the L∞ = Lmax/0.95 (Pauly 1984; Hordyk et al., 2015). The theoretical age (t0) was estimated using the empirical equation by Pauly (1980) (Ernawati et al., 2015).

Mortality Parameters

The natural mortality rate (M) was estimated with the empirical equation of Pauly (1980) by using data on the mean annual water surface temperature (T) (Ernawati et al., 2015). For estimated total mortality (Z) used carapace width data from each sex and analyzed by using a menu of the length converted catch curve in the FISAT II software (Sparre & Venema 1999). Fishing mortality (F) and exploitation rate (E) were calculated using the formula proposed by Pauly (1984).

RESULTS AND DISCUSSION

Group The Distribution of Carapace Width

The distribution of carapace width showed a different number of class intervals between males and females (Figure 2). The carapace width for each sex was grouped in a frequency distribution of carapace width with a range of mean values from 43.95 mm to 173.95 mm. The frequency distribution of carapace width showed only one class mode of normal distribution. Based on the analysis of the forward motion mode by Bhattacharya (1967), it is known that male and female BSC had an age structure group (cohort) because the frequency distribution of carapace width cannot be separated into several normal distributions.

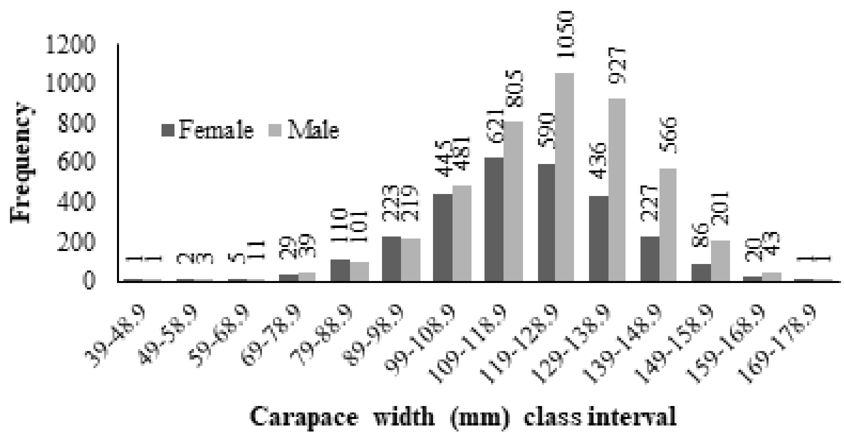

Figure 2. Frequency distribution of Blue Swimming Crab carapace width

The range of carapace width in this study in the range of 47-174 mm for males and 39-176 mm for females. The range of carapace width of BSC in other locations is different (Table 1). The maximum carapace width obtained was more significant than the waters of Brebes (Sunarto, 2012), Lasongko Bay (Hamid & Wardiatno 2015), Cirebon (Ernawati et al., 2017), Jakarta Bay (Panggabean et al., 2018) and smaller than the Aru Islands (Kembaren & Surahman 2018).

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Table 1. Wide range of carapaces in various Indonesian waters

Location of Water	Sex	Wide Range of Carapace (mm)	Source
Brebes Coast, Central Java	Male	22 - 75	Sunarto, 2012
	Female	21-74	
Lasongko Bay, Central Buton	Male	49.8 - 147.7	Hamid & Wardiatno 2015
	Female	52.1 - 162.2	
Cirebon	Male	71.1 - 151.3	Ernawati et al., 2017
	Female	60.0- 152.6	
Jakarta Bay	Male	60 – 145	Panggabean et al., 2018
	Female	60 – 150	
Kepulauan Aru	Male	92.5 – 183	Kembaren & Surahman 2018
	Female	92.5 – 181	
Banten Bay	Male	47-174	This study
	Female	39-176	

The interval of carapace width in this study has a smaller value compared to the Kepulauan Aru, which is caused by the fishing pressure or the number of crab fishing gear in the Kepulauan Aru than the Banten Bay (PT. Multi Area Desentralisasi Pembangunan, 2021). Diverse results have been reported namely the carapace width in Jakarta Bays was found smaller than those found in this study, due to habitat degradation and pollution that lead to a decrease in water quality (Nugraha et al., 2020); the smaller carapace width was found in Lasongko Bay as they were obtained from shallow water (10 m-35 m) with the highest carapace width 73 mm (10 m-35 m) with the highest carapace width 73 mm (Hamid & Wardiatno 2015); larger than the waters of Cirebon because differences were using of fishing gear in form of dredge nets with fishing areas around nearshore areas such as estuaries (Ernawati et al., 2017). The difference in carapace width range can be caused by different environmental factors and fishing pressure. According to Edgar (1990), adult crabs prefer substrates textured with sand or sandy mud in shallow waters up to 50 m deep. Nitiratsuwan et al., (2010) stated that adult crabs with a carapace width of more than 100 mm were found in coastal areas up to deeper waters. Therefore, maintaining the sustainability of the BSC population becomes important (Ernawati et al., 2015).

The Carapace Width and Weight Relationship

The BSC carapace width (L) can explain their growth, while BSC weight (W) is a function of carapace width. The relationship between carapace width and weight followed the equation W=8,8336 L^(3,4383) for males and =3,8455 L^(3,1143) for females. The result of the coefficient determination (R^2) was close to 1, it indicated a very high level of closeness, where the increase in carapace width affects the increase in weight (Figure 3). The relationship between carapace width and weight describes the BSC growth pattern. Based on the relationship between carapace width and weight in this study, both males and females obtained a slope value of growth coefficient (b) >3 (Table 2). This condition is classified as positive allometric (Effendie 2002; Ernawati et al., 2014). Positive allometric growth patterns indicate that weight gain is faster than the increase in carapace width.

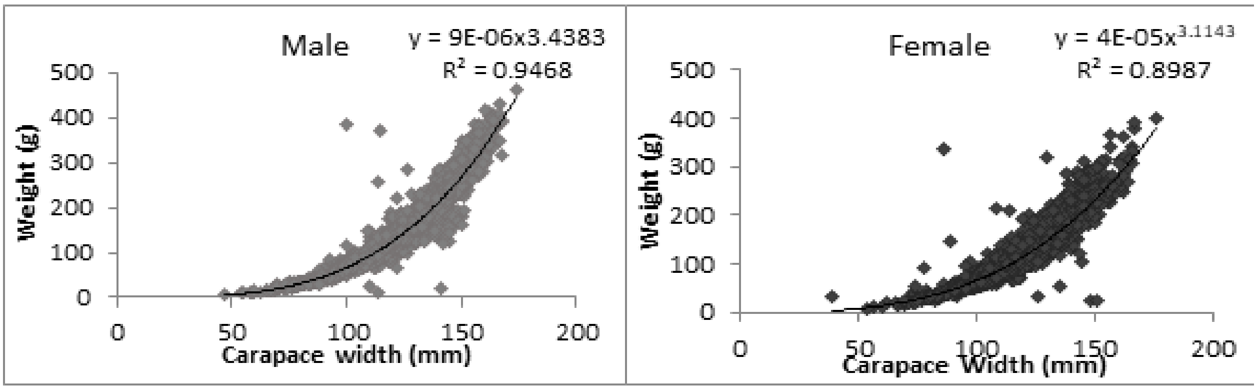

Figure 3. The BSC carapace width and weight relationship

Table 2. The analysis results in relationship between carapace width and weight

Sex	a	b	R^2	t- Test	Growth Patterns
Male	8.8336	3.4383	0.9468	t count >t table	Positive allometric
Female	3.8455	3.1143	0.8987	t count > t table	Positive allometric
Combined	1.3742	3.3403	0.925	t count > t table	Positive allometric

Research by Safaie et al., 2013 in the coastal waters of the Persian Gulf and the Gulf of Oman, Iran showed similar results with a slope value of b>3 but the regression coefficient (r) was relatively lower for both sexes. Research by Fauzi et al. (2018) in the same waters, had different results for male BSC positive allometric and female BSC negative allometric. The growth patterns can differ between seasons and locations, as according to Ernawati et al. (2014) that differences in the results of the relationship between carapace width and weight in several waters location are influenced by several factors, including sex, reproductive process, water temperature, salinity and food (quantity, quality, and size). The reproductive process or the level of mature BCS was more in the West monsoon (Ernawati et al., 2014), which causes the weight of female crabs to tend to increase because there are eggs in the abdomen.

The constant value b of male crabs is greater than female crabs, indicating that at the same size, male crabs are larger than female crabs. Sukumaran & Neelakantan (1997) stated that the growth patterns of male and female crabs are influenced by differences in feeding habits. Josileen (2011) stated that in females that are incubating eggs, pre-molting, and in the process of gonad maturation, they stop or eat very little.

Growth Parameters

Based on the growth parameters estimation, the asymptotic length ($L\infty$) of males was 176.75 mm, while for females was 176.46 mm (Table 3). The maximum length in this study of both male and female crabs was smaller than Pati Waters (187 mm) (Ernawati et al., 2015) and Kalimantan (204.3 mm) (Suman et al., 2020), but greater than Jakarta Bay waters (142.5 mm) (Wagiyo et al., 2019) and Jepara waters, and Central Java (169.80 mm) (Setiyowati 2016). Differences in growth parameters of various water locations are caused by differences in environmental conditions and fishing pressure in each water location. Factors of quantity and quality of food in the habitat greatly affect the availability of energy to carry out metabolic processes. High fishing pressure can disrupt the crab growth process in nature (Kembaren et al., 2012). High fishing pressure is thought to cause higher fishing mortality than natural mortality causing the crabs to have no opportunity to grow, resulting in few old crabs being found (Sparre & Venema, 1999).

Table 3. The growth parameter of BSC in Banten Bay

Parameters	Male	Female
$L\infty$	176.75 mm	176.46 mm
K	1.2 /year	1.15 /year
-to	-0.1179	-0.1129

The growth rate (K) of males and females was 1.2 per year and 1.15 per year (Table 3). It obtained a value of more than one (K > 1). This indicates that BSC growth is relatively fast, and the time to reach maximum size is also faster. As a result BSC tends to have a short lifespan (Setyawan & Fitri 2018). K of males was greater than that of females. The difference was due to the female BSC using some energy for gonad development (Kembaran et al., 2012). Therefore, the metabolic process in female decreases and body development is inhibited.

The K value for female BSC in Banten Bay waters is greater than that from the Gulf of Thailand waters (K = 1.13 per year), but for males has a smaller K value (Kunsook et al., 2014). Meanwhile, the K value in this study is greater than Kendari waters with a value of K = 0.91 per year (Suman et al., 2018) and is smaller than the waters of Oman Iran, Pakistani and the Philippines (Safaie et al., 2013, Afzaal et al., 2016, Abrenica et al., 2021). Differences in K values in different waters can be caused by environmental conditions (food availability) and exploitation rates (Ernawati et al., 2017). If the availability of sufficient natural food in the habitat will cause relatively faster growth of crabs as the energy supply needed for the metabolic process is sufficient. Growth of each organism will generally begin to slow with age, while fishing pressure or high exploitation rates disrupt the crab growth process which results in a change in population structure and reproductive strategy of crabs resources, so that to maintain the sustainability of the population, crabs reproduce at a relatively small size (Ernawati et al., 2015).

Mortality and Exploitation Rate

Total mortality estimation (Z) of male and female BSC in this study used catch curves linearized against BSC carapace width (Figure 4). BSC's mortality value in Banten Bay in the West monsoon was 1.25/year for males and 1.22/year for females (Table 4) with input the average water temperature parameter in this study of 29.3°C obtained from satellite image analysis. Average water temperature affects each of the life stages of BSC, Kangas (2000) explained that adult crabs only molt once a year. During winter period growth rate of BSC was slow because the water temperature decreased. BSC was able to adapt to a wide temperature range of 27-31.5°C (Sunarto 2012; Ernawati et al., 2015; Hamid, 2015).

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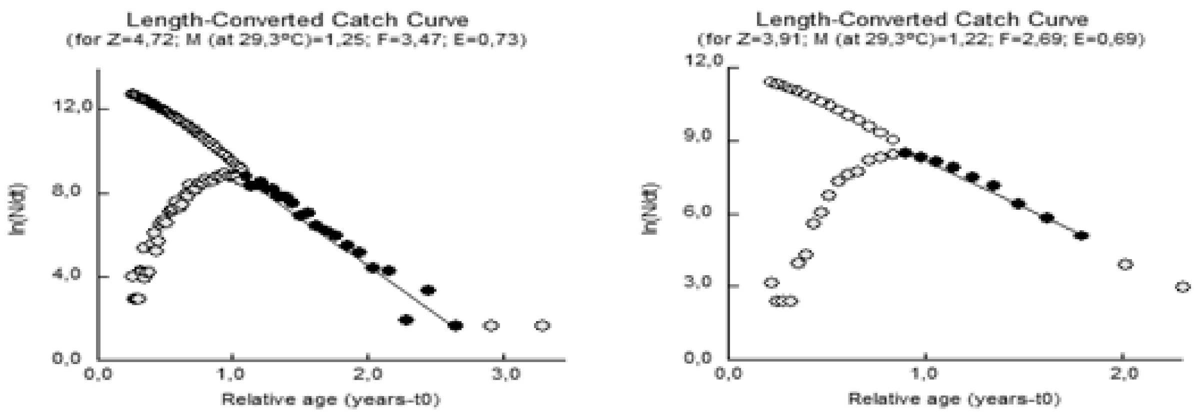

Figure 4. Linearized catch curve

Table 4. Mortality and exploitation rates of BSC in Banten Bay

Parameters (per year)	**Male**	**Female**
Total Mortality (Z)	4.72	3.91
Natural Mortality (M)	1.25	1.22
Fishing Mortality (F)	3.47	2.69
Exploitation (E)	0.73	0.69

The obtained mortality values showed that the capture mortality value (F) was greater than the natural mortality value (M). This indicates that BSC's mortality in Banten Bay is thought to be more influenced by fishing activities rather than natural factors. Furthermore, the exploitation rate values of males and females exceeded the optimum exploitation value of BSC, which is 0.5/year. This high mortality was the result of overfishing. According to Sparre & Venema (1999), if the fishing mortality rate is higher than natural mortality it indicates strong growth of overfishing which causes a small number of adult crabs to be found.

A Study about the BSC mortality rate in Banten Bay has been done before by Diskibiony (2010) that obtained a natural mortality value of 0.205 /year and a fishing mortality rate of 0.1629/year with an exploitation rate below the optimum value of 0.4847/year. The significant difference in mortality and exploitation rate values is due to the continued increase in BSC fishing activities. On the other hand, Wagiyo et al., (2019) obtained a natural mortality rate of 1.24/year, fishing mortality of 3.63/year, and an exploitation rate of 0.75/year in the waters of Jakarta Bay. Differences in mortality rates in different waters can be caused by differences in fishing pressure and environmental conditions.

CONCLUSION

Blue Swimming Crab age structure during west monsoon shown as one cohort. The growth characteristics of male and female BSC in Banten Bay Waters are positive allometric (b>3) with an asymptotic length for males of 176.75 mm and females of 176.46 mm. The fishing mortality value (F) of 3.47/year for males and 2.69/year for females is greater than the natural mortality value (M) of 1.25/year for males and 1.22/year for females which indicates mortality is thought to be more influenced by fishing activities. The exploitation rate (E) values obtained for males and females were both 0.73/year and 0.69/ year, it was above the optimum exploitation value of 0.5/year.

AUTHOR CONTRIBUTION

I.A., A.R. and M.A.K. designed and conducted the research, and article writing. M.S. and M.W. assisted in data collection. S.J.R helped to create the research map. W.A helped to fix sentence construction.

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CONFLICT OF INTEREST

The authors declare in writing this article there is no conflict of interest.

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