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# Growth of Mud Crab (*Scylla tranquebarica* Fabricus, 1798) in the Estuary of West Segara Anakan, Cilacap, Indonesia

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**Abstract**

Mud crab (*Scylla tranquebarica*) is one of the important fisheries comodity in West Segara Anakan. However, the information concerning on its biological population is still limited. This study aims to analyze the growth of mud crab including the size distribution, carapace width-weight relationship, condition factors, and growth parameters. The study was conducted from June 2016 to May 2017 in the estuary of West Segara Anakan. The total of 271 samples were collected during this study to observe the growth of mud crab. The result shows that the carapace width distribution frequencies of male and female mud crab were considered to be normal distribution with a majority of catch were on sub-adult life stage (70-120 mm width). Linear regression showed that male mud crab has isometric growth pattern, while the female one has a negative allometric growth pattern ($P<0.05$). Mud crab has a maximum condition factor value in November for male, and in December for female. Based on Electronic Length Frequency Analysis (ELEFAN I), asymptotic carapace width ($CW\infty$) value were 190.05 mm for male, and 163.00 for female. Growth coefficients (K) for male and female were 0.29 and 0.39, respectively.

***Keywords:*** Carapace width and body weight relationship; condition factor; growth parameters; *Scylla tranquebarica*; West Segara Anakan.

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## 1. Introduction

Mud crab (*Scylla* spp.) is included as one of the important fisheries commodity with high economic values in Southeast Asia [6, 20]. This commodity also has significant potentials to be developed in the field of aquaculture [13, 24, 32] with an average annual production reaching up to 24,000 tons in the Western Indo-Pacific Region. The mud crab has an increasing popularity due to its large size and nutritious meat quality [22]. In Indonesia, the commercial exploitation of mud crab has been carried out since 1980. Nonetheless, to meet the growing demand for mud crab, most of the production still derives from the capturing wild population [5].

Mud crab has an variant habitat distribution in muddy estuaries, intertidal swamps, brackishwater ponds, mangrove swamp area, and even oceans [4, 14, 22]. The author in [17] identified this species in both intertidal and subtidal zones. However, adult crab tends to live in subtidal zones in which it buries itself in the mud. In Indonesia, mud crab is widely distributed from the west (Sumatera) to the east (Papua). In Segara Anakan, mud crab is caught on estuary canals and on the edge of the mangrove ecosystem.

Segara Anakan is located on the South Coast of Java. Administratively, it belongs to Kampung Laut District of Cilacap Regency. This area is included in the Segara Anakan area located in the downstream of Citanduy River. In reference to [30], the area is divided into protected areas, buffer zones, and utilized areas [9].

Based on the study conducted by the author in [2, 37], the mud crabs in Segara Anakan consists of three species; i.e. *Scylla tranquebarica, Scylla serrata,* and *Scylla olivacea,* in which *Scylla serrata* species becomes the main catch commodity in the region. Moreover, specifically in West Segara Anakan covering the areas of Citanduy River, Majingklak, Cibereum River, Segara Anakan Lagoon, Kampung Laut village to West Pelawangan, mud crab (*S. tranquebarica*) tends to dominate the catch. Nonetheless, the studies on mud crab in West Segara Anakan by far are still limited, especially on the type of *S. tranquebarica*. Destruction towards mangrove ecosystem will have a significant impact on the mud crab population [21]. Excessive habitat degradation and over-exploitation in Indonesian waters have resulted in a decrease of the mud crab population [5]. In maintaining the sustainability of the mud crab, a number of efforts to improve and manage the resource potential of the mud crab both optimally and sustainably are required. To support such efforts, it is necessary to provide various information that can be used as the basis for the resource management of mud crab, one of which is on the growth aspect of mud crab in the natural habitat. The results of this study on the growth of mud crab can be applied to determine the optimized catch rate as the basis for the management policy of mud crab. This study aims to analyze size distribution of mud crab catches, the relationship between carapace width and body weight, condition factor, and growth parameters of *S. tranquebarica* in West Segara Anakan. The results of this study are expected to be beneficial as the basis for optimal and sustainable resource management of *S. tranquebarica*.

## 2. Materials and methods

### *2.1 Time and study area*

The study was conducted from June 2016 to May 2017 in the estuary of West Segara Anakan. Sampling was conducted once a month. Mud crab was caught by using bamboo traps. The traps were setting for one night at

the six sampling sites i.e. West Pelawangan (St. 1), Majingklak area (St. 2), Citanduy River (St. 3), Cibeureum River (St. 4), Segara Anakan lagoon (St. 5) and Kampung Laut area (St. 6) (Figure 1).

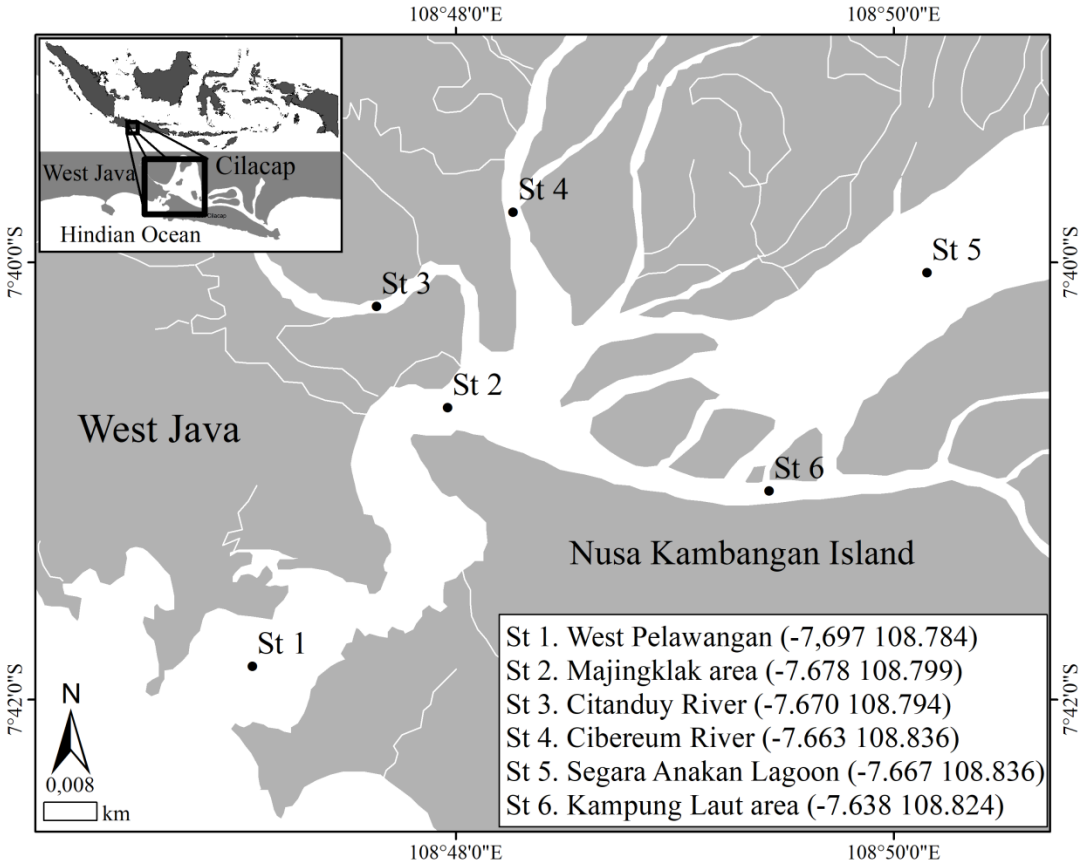


**Figure 1:** Map of study area in the estuary of West Segara Anakan

### *2.2 Samples analysis*

The identification of mud crab was conducted in reference to the author in [15]. *S. tranquebarica* is characterized by its greenish to black color of carapace with slightly brownish lines on its swimming legs; frontal lobe spines of *S. tranquebarica* are moderate height (mean height approximately 0.04 times frontal width measured between medial orbital sutures), blunted with rounded interspaces; and carpus of chelipeds with two obvious spines on distal half of outer margin. The samples of mud crab that had been identified were subsequently observed the carapace width, weight and sex. The measurement of carapace width (mm) was conducted using calliper with a precision of 0.05 mm and both ends of the 9$^{th}$ anterolateral spine was measured. Weighing were performed by a digital scale (with a precision of 0.01 g). Meanwhile, sex determination were conducted through morphological observation by examining the shape of abdominal flap. Male *S. tranquebarica* has tapered abdomen, while the female one has rounded abdomen.

### *2.3 Data analysis*

#### *2.3.1 Carapace width distribution frequency*

The frequency of carapace width in each class was plotted in a graph to show its normal distribution. The graph shows the peaks that indicating the number of the existing age groups (cohorts), and it also shows the class distribution shift of carapace width every month. The shift characterizes the number of existing age groups (cohorts), and if there is a shift in the frequency distribution mode of carapace width, it indicates the presence of more than one cohort. If such condition occurs, it is necessary to separate the normal distribution.

### *2.3.2 Carapace width and weight relationship*

The analysis of carapace width and body weight of male and female *S. tranquebarica* was conducted separately by using equation of the author in [19] as follows:

$$W = aCW^b \quad (1)$$

in a condition that W is the body weight of mud crab (g), CW is the carapace width (mm), a is intercept, and b is slope of the curve [8]. Constants of a and b were estimated by using the linear regression analysis method.

The b value were statistically examined by using the partial test (t-test) with a 95% confidence level to anticipate the weakness of the obtained results based on the established hypothesis ($H_0$: b=3 and $H_1$: b≠3). The decision was taken by comparing the $t_{count}$ value and the $t_{table}$. The b=3 value indicates an isometric growth pattern, while the b≠3 value indicates an allometric growth pattern. If b>3, mud crab has a positive allometric growth pattern, and if b<3, then they have a negative allometric growth pattern.

### *2.3.3 Condition factor*

The condition factor was analyzed by using the Fulton condition factor (K) [3, 8, 19]. The equation of Fulton condition factor is formulated as follows:

$$K = 10.000W/CW^3 \quad (2)$$

in which K is the condition factor, W is the body weight (g) and CW is the carapace width (mm).

### *2.3.4 Growth parameters*

The estimation of growth parameter was conducted through ELEFAN I (Electronic Length Frequencys Analysis) program included in FiSAT II (FAO-ICLARM Fish Stock Assessment Tool) in reference to the growth formula proposed by von Bertalanffy [36]:

$$CWt = CW\infty\ (1 - e^{[-K(t - t0)]}) \quad (3)$$

To determine $t_0$, empirical equation of the author in [29] was utilized:

$$\log(-t_0) = 0{,}3922 - 0{,}2752(\log CW\infty) - 1{,}038(\log K) \quad (4)$$

CW∞ is the theoritical maximum carapace width (asymptotic carapace width), K is the coefficient of growth rate (per unit time) and $t_0$ is the theoretical age when the total carapace width is equal to zero.

## 3. Results and discussion

### *3.1 Results*

#### *3.1.1 Carapace width distribution frequency*

The distribution method of the carapace width frequency is beneficial to estimate the size distribution of mud crab by referring to the growth traits and the influencing factors. The distribution chart of mud crab carapace width frequency for one year observation is presented in Figure 2, and the distribution chart of the carapace width frequency in monthly observation is presented in Figure 3.

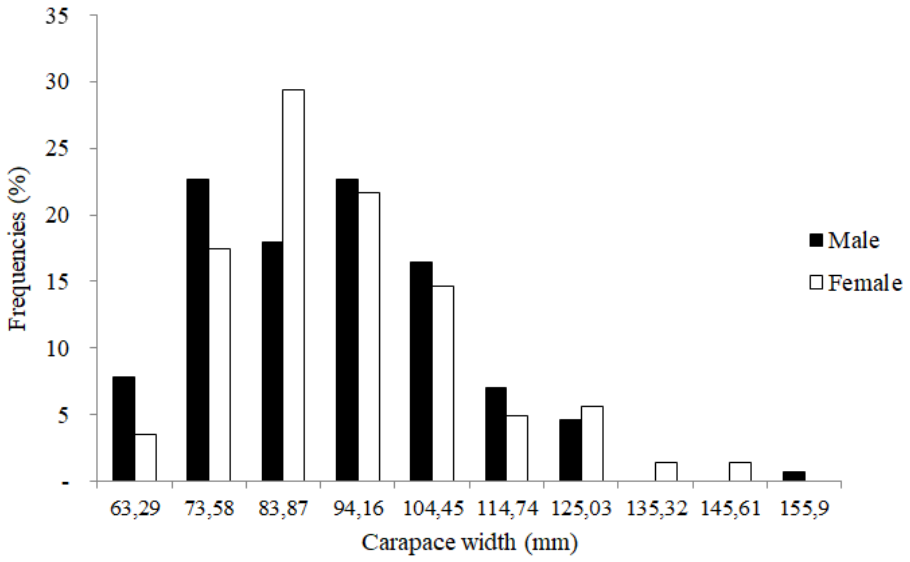


**Figure 2:** Carapace width distribution frequency of mud crab *Scylla tranquebarica* in West Segara Anakan

In reference to Figure 2, it is evident that male mud crab dominate the catch in the mean size of 63.29 mm, 73.58 mm, 94.16 mm and 114.74 mm. Meanwhile, female mud crab dominate in mean size of 83.87 and 125.03 mm. At an average size interval of 135.32 mm and 145.61 mm, only female was caught; while in the average size of 155.90 mm, only male was caught. The highest frequency of mud crab catching in male is in the average size of 73.58 mm and 94.16 mm; and female in the average size of 83.87 mm. In the increasing of size, the frequency of male and female mud crab were tends to decrease.

An analysis of the monthly distribution of carapace width frequency was conducted to examine the mode shifting that occurred in monthly observation. The mode shifting indicates a growth in the mud crab population in nature. In reference to Figure 3, there was a shift in the size of the mud crab carapace width during observation, in both male and female mud crab. This indicates that the growing size of carapace width occurred periodically. In male mud crab, the mode shift in carapace width ranged from July to September, and December

to March. In female mud crab, mode shifting occurred between October to December, and January to April.

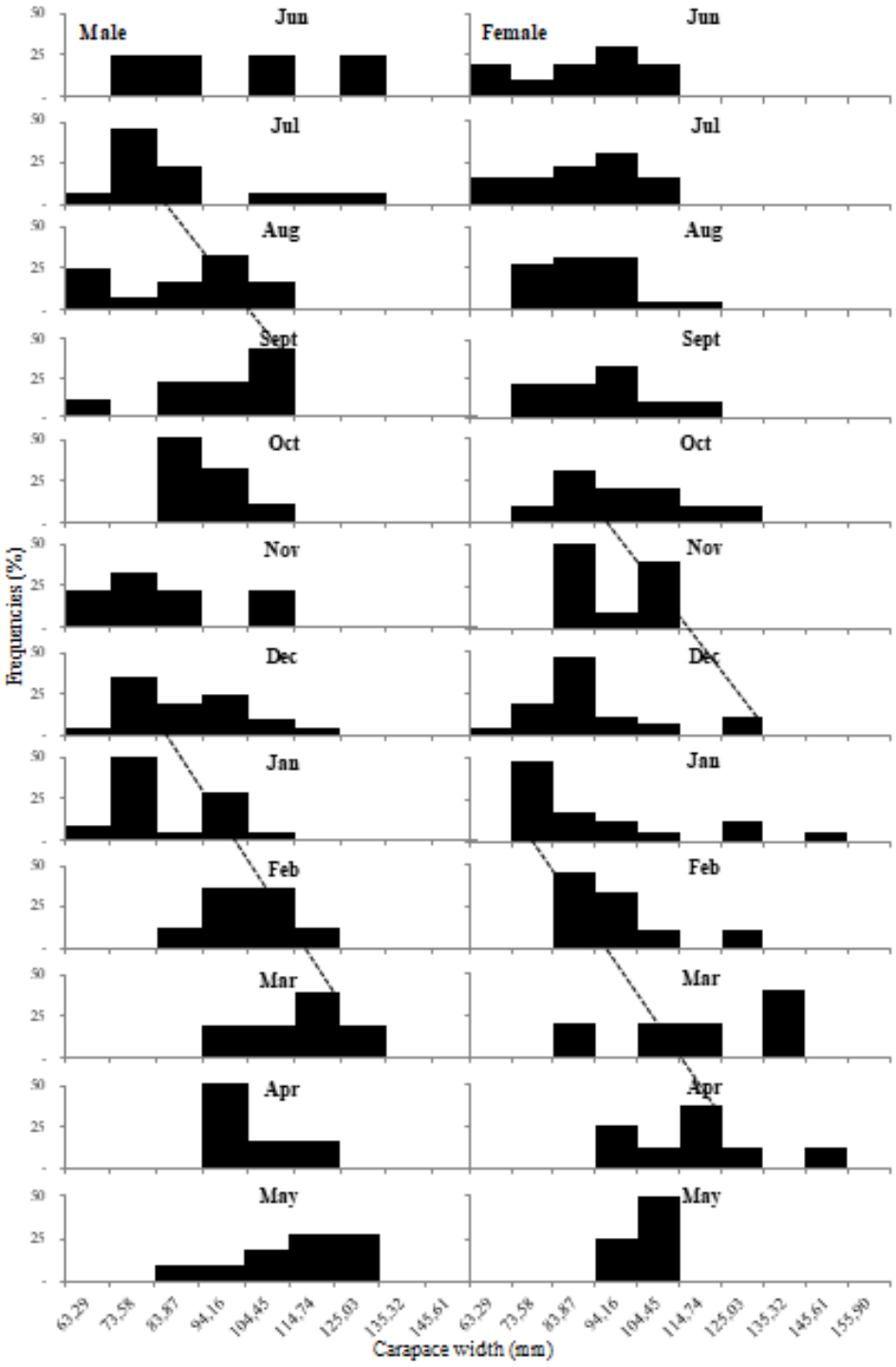


**Figure 3:** Monthly carapace width distribution frequency of mud crab *Scylla tranquebarica* in West Segara Anakan

### *3.1.2 Carapace width and weight relationship*

The relationship between carapace width and weight is useful to show the assertion that the mud crab weight is a

function of the carapace width. The width of the carapace and body weight correlate and form a non-linear relationship, where the width of the carapace is the independent variable that affects the weight as the dependent variable. This means that changing the width of the carapace in a particular interval is not always followed by a change of weight in the same phase. The graph of the carapace width and weight relationship in mud crab is presented in Figure 4.

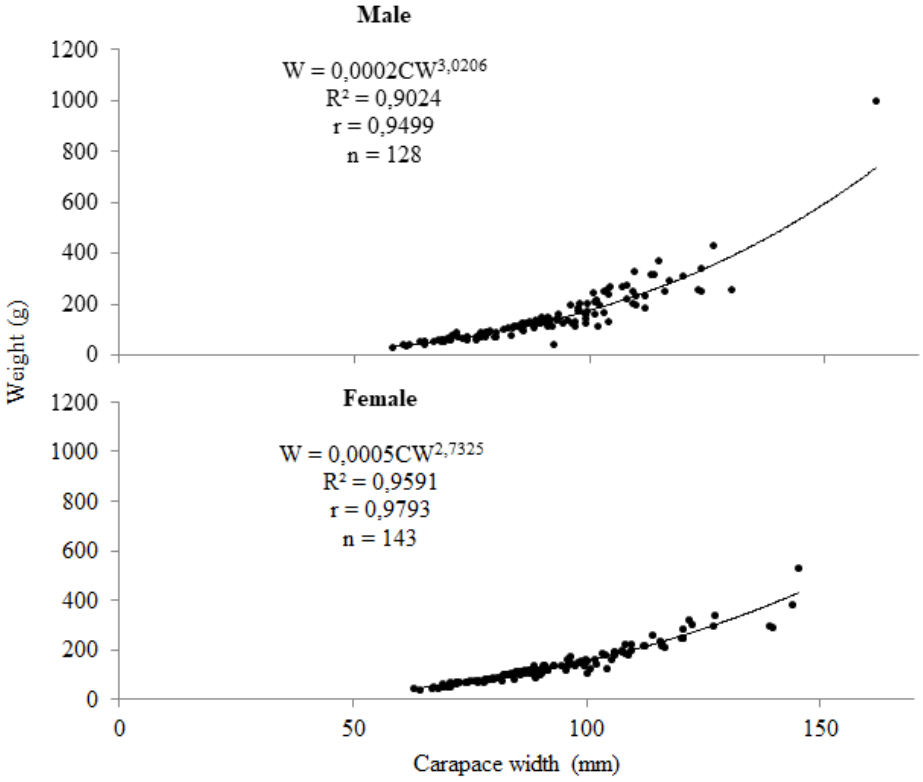


**Figure 4:** Relationship between the carapace width and weight of crab *Scylla tranquebarica* in West Segara Anakan

A total of 271 individuals of mud crab were obtained during the period of June 2016 to May 2017 with a total of 128 male mud crabs and 143 female mud crabs. Based on the equation $W=aCW^b$, an equation of relationship between the carapace width and weight was obtained in which male mud crab weight is $W=0.0002CW^{3.0206}$ and female weight is $W=0.0005CW^{2,7325}$.

Male mud crab has a larger b value than female i.e. 3.0206 for male and 2.7325 for female. The coefficient of determination ($R^2$) shows that the mud crab carapace width is able to describe its weight that is by 90.24% for male and by 95.91% for female. Based on the correlation coefficient (r), the relationship of carapace width and weight of both mud crab in both male and female is very close.

The result of the predicted growth pattern based on Analysis of Variance (ANOVA) showed that male mud crab has an isometric growth pattern ($P < 0,05$) and female mud crab has a negative allometric growth pattern ($P < 0,05$). This means the growth of male mud crab does not dominate between the growth of carapace width and its weight. In female mud crab, the growth of carapace width is more dominant than the growth of weight.

### *3.1.3 Condition factor*

Condition factor defines the fatness level of mud crab as a result of the response to environmental conditions based on the relationship of carapace width and weight. The influence of environmental conditions is one of the major factors determining the time-based growth rate of carapace width and weight.

The responses of these effects can be observed with the quantitative variables that facilitate in comparing the magnitude of the responses of environmental factors to the growth of each individual mud crab. The variation distribution of the condition factor values of the male and female mud crab is presented in Figure 5.

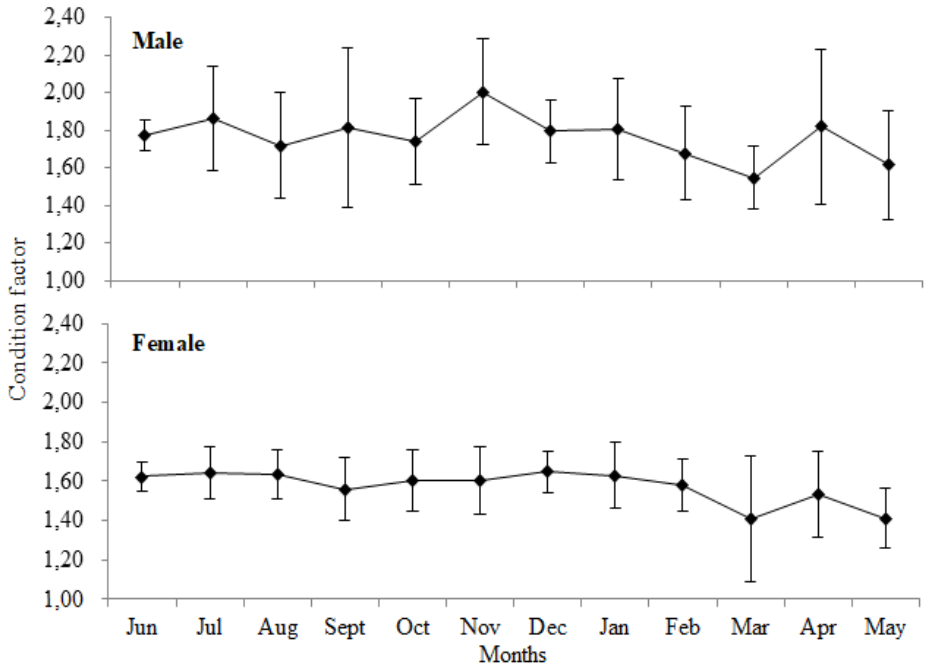


**Figure 5:** Condition factor of mud crab *Scylla tranquebarica* in West Segara Anakan

Female mud crab has a distribution of condition factor values that tend to be more stable than the male during the observation. The highest condition factor of male mud crab was in November with the condition factor value of 2.0014±0.1684, and the lowest was in March with the value of 1.5453±0.4100.

The mean value of the condition factor of male mud crab was 1.7632±0.1189. Meanwhile, the highest condition factor of male mud crab was in December of 1.6473±0.1029, and the lowest was in March of 1.4086±0.3205. The mean value of the condition factor of female mud crab was 1.5335±0.0836.

### *3.1.4 Growth parameters*

The estimation of growth parameter (CW∞) in ELEFAN I analysis was performed in reference to Power-Wetherall plot. The K value was obtained from the K scan menu. The estimated result of mud crab growth parameter is presented in Table 1 and Figure 6.

**Table 1:** Growth parameter (CW∞, K and $t_0$) of mud crab of *Scylla tranquebarica* in West Segara Anakan

| ***S. tranquebarica*** | **CW∞ (*mm*)** | **K (*per year*)** | **$t_0$ (*years*)** |
|---|---|---|---|
| Male | 190,05 | 0,29 | -0,3457 |
| Female | 163,00 | 0,39 | -0,2651 |

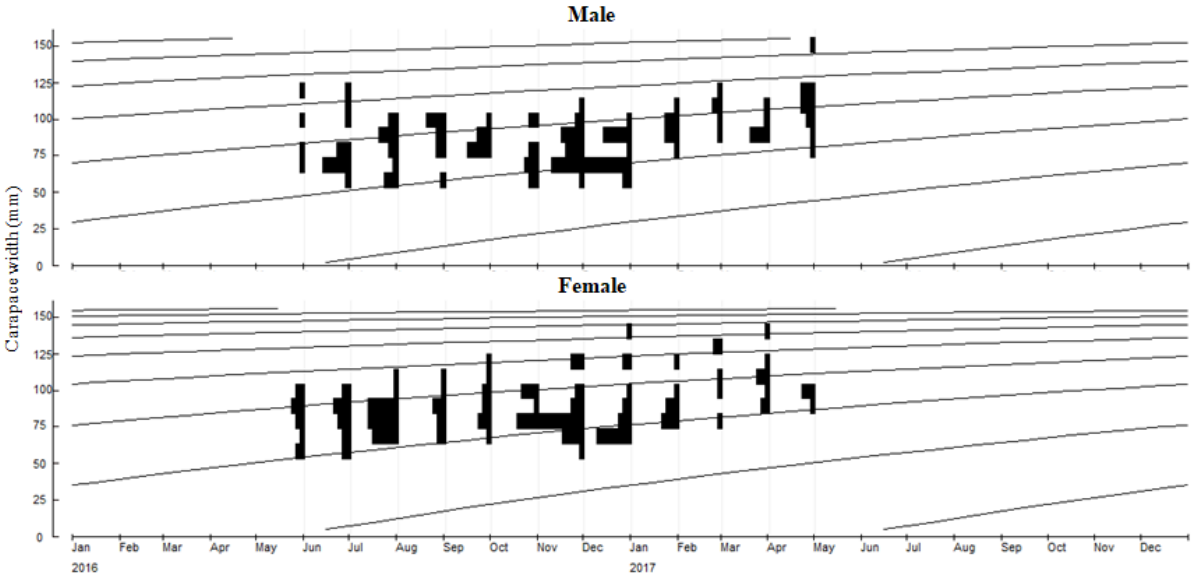


**Figure 6:** The von Bertalanffy growth curve of mud crab *S. tranquebarica* in West Segara Anakan

Male mud crab hasa n asymptotic carapace width value (CW∞) of 190.05 mm, while female mud crab has a lower CW i.e. 163.00 mm. The growth rate (K) of male mud crab is 0.29 lower than female, which is 0.39. The period in which male mud crab have a carapace width equals to zero ($t_0$) is -0.3457 year and the $t_0$ value of female mud crab is -0.2651 year.

### *3.2 Discussion*

The carapace width frequency distribution of mud crab spreads normally with the peak frequency in the mean size of 82.32 mm for male and female. The decreasing frequency of carapace width in lower and higher size indicates the effect of the mouth opening size of the fishing gear used by fishermen [41]. Consequently, it is assumed that mud crab with an average size under 62.98 mm was unable to be trapped in fishing gear; and mud crab with an average size above 140.34 mm was unable to fit into the fishing gear.

The author in [17] has classified the caught of mud crab into three stadia categories in reference to the size of carapace width; i.e. juvenile (with a carapace width of <70 mm), sub-adult (with a carapace width of ≤70-120 mm), and adult (with a carapace width of >120 mm). Based on these categories, it is identified that the male mud crab caught in West Segara Anakan was 13% juvenile, 83% sub-adults and 5% adults whereas the caught female mud crab was 6% juvenile, 88% sub-adult and 6% adult.

According to the author in [10], female mud crab has a migration habit towards the ocean to reproduce, while male mud crab remains in mangrove habitat. Therefore, the population of mud crab in mangrove habitat is often dominated by male crab. However, in this study, the mud crab captured was dominated by female mud crabs. Such situation was considered to be due to the majority of mud crab being in sub-adult phase (the carapace width of 70-120 mm) and had not reached the gonad maturity size yet. Subsequently, it is not influenced by the migration pattern of female mud crab. In addition, differences in sex dominance of the caught crustaceans in various locations were also influenced by differences in life span, season, geographical conditions, mortality, growth rate, and reproduction [7].

An analysis on carapace width-weight relationship is significantly essential in this study. According to the author in [11], difficulties have started to emerge in the measurement of spiny crab; including mud crab. This is primarily because the body parts of the crab are easily damaged. Hence, the results of mud crab measurements are fairly beneficial in converting body weight value into carapace width value with only limited information on the body weight, or by using carapace width-weight regression results to estimate the carapace width value out of its body weight in encountering difficulties and insufficient time to measure the carapace width.

An analysis on the carapace width-weight relationship to date has been the most widely used parameter in crustacean studies. The carapace width-weight relationship can be utilized to estimate index conditions and ontogenetic analysis, along with parameter estimation of fish and crustacean population dynamics. These parameters can also be used to indicate the condition, or to estimate the amount of crab meat to be consumed based on the size and its biomass. As the carapace width-weight relationship has a practical value, it is highly possible to convert the carapace width into weight and vice versa. Through this parameter, the mud crab population can be managed by establishing limitation for the catching [11].

The mud crab growth pattern, in reference to the t-test results, indicates that male mud crab has an isometric growth pattern, while female has an allometric negative growth pattern ($p<0.05$). As argued by the author in [39], the negative allometric growth pattern in female mud crab occurs because female crustaceans require more food intake for moulting and gonad maturation process. The moulting process performed by any female mud crab will lead to the copulation process; as a result, the female mud crab grow more on their carapace width. The moulting process is less common in male mud crab; therefore, food intake tends to be absorbed to lengthen and magnify the claws (chelae) which hold an important role in the mating process.

According to the author in [12], the large size of claws in adult male mud crab serves to hold the female during mating period; i.e. when both are in doublers position, as well as to reverse the body of the female as the copulation process takes place. The large and powerful claws of male mud crab also function to fight against other male in an effort to defend the mating territory, defend themselves from predators, and protect their female mating pair. This is because towards the copulation, female crab conducts moulting which causes it to have soft-bodied and be vulnerable towards attacks and predation of other mud crab due to their nature of cannibalism. The author in [28] states that due to the large claw size of male mud crab, if they are on the same size as the carapace width, the male mud crab has a greater weight than female.

The $W=aCW^b$ equation shows that b value of male mud crab is greater than that of female. Similar results were also obtained in a study conducted by the author in [38], who was examined the relationship of length-weight and carapace width-weight of *S. tranquebarica* at the Parangipettai Coast. The b value of male mud crab greater than that of female is also evident in *S. serrata* and *S. tranquebarica* in Chilika Lagoon Waters in India [25]; *S. serrata* in Mantehage Waters, Bunaken National Park, North Sulawesi [33]; and *S. serrata* in Sundarbans Mangrove Waters, Bangladesh [1]. The author in [23] stated that b value of male crab is higher than that of female as observed in other Brachyura (crab-crust) groups. The author in [38] revealed that b value of male is greater than female indicating that male individuals are heavier than female. It also indicates a difference in eating habits as well as metabolic rates between male and female mud crabs. Meanwhile, according to the author in [18], this is due to the ratio of body weight to carapace width of male mud crab in sub-adult and adult phases is greater than female due to its larger claw size.

In addition to obtaining information on the growth patterns of mud crab, an analysis on the relationship between carapace width and weight, the author in [39] also obtained information on the interrelation between carapace width and weight variables in reference to the correlation coefficient value (r). Hence, it can be determined whether the individual body weight in a population of mud crab can be determined by referring to its body size. The significant correlation coefficient value in this study indicates that mud crab biomass in West Segara Anakan can be predicted by identifying the size of carapace width.

According to the author in [8], the condition factor (ponderal index) is an index utilized to indicate the condition or the state of organisms, in terms of physical capability for survival and reproduction. Meanwhile, according to the author in [3], the condition factor is commonly used to compare the condition of aquatic organisms in reference to sex, season and habitat location differences. The highest condition factor value of male mud crab is in November, and that of the female ones is in December due to the influence of abundant mud crab in nature and the reproductive season.

As argued by the author in [16], this is caused by the condition factor measured from the monthly obtained samples that can be used to determine the seasonal variations or temporal distribution of the aquatic organisms. In addition, it is presumably influenced by the abundance of natural food and their production maturity level. Nonetheless, the condition factor values of mud crab tend to be stable during the observation, especially in the case of female mud crab. The stability of the condition factor is assumed to be caused by the reproductive behavior of mud crab spawned throughout the year [25].

The condition factors of male and female mud crab vary with an average value ranging up to 1.000. This is similar to the results of the studies conducted by the author in [2], who was examined the condition factor of *S. serrata* in Segara Anakan; Chilika Lagoon [25]; Coastal of Mayangan, Subang [34]; and in the West Seram Coastal Waters, Maluku [35]. According to the author in [35], the ideal condition of organisms will be achieved if the condition factor value tends to be in a narrow range. The range of condition factor values is determined by location, season, gonad maturity, and food availability [19] in which the range of condition factor values approaching 1.000 indicates that mud crab grow and reproduce well [35].

Estimation of growth parameters on crustaceans derived from nature tends to be difficult due to the existence of moulting [40]. Most studies of crustacean growth were conducted within the cultivation system and by the method of tagging [17], as conducted by the author in [27, 40]. In this study, growth parameters were assumed based on carapace width databases using ELEFAN I method integrated with FiSAT II program as conducted by the author in [17].

The CW∞ value of male mud crab is greater than that of female. In contrast, the growth coefficient (K) of male mud crab is smaller than that of the female. This suggests that female mud crab grow faster than the male. According to the author in [36], the growth coefficient value (K) has a role as a determinant of how rapid the mud crab carapace width reaches its asymptotic length (CW∞) or its maximum length. The high growth coefficient value takes short time to reach its asymptotic length. The faster growth rate in female mud crab is presumed to be caused by their more frequent moulting experience than the male mud crab [39].

The value estimation of $t_0$, CW∞ and K in this study indicates distinct results from some other studies of mud crab growth in different locations. A study on *S. serrata* growth parameters, conducted by the author in [39] in the mangrove habitat of Kutai National Park highlighted that the CW∞ values ranged from 143 to 155 mm, and K values ranged from 0.45 to 1.5; In examined *S. serrata* species in the waters of Kwandang District, North Gorontalo, the author in [26] obtained CW∞ value of 188.49 mm and K value of 0.39; the author in [41] observed *S. olivacea* in Setiu Wetland, Terengganu, Malaysia, obtained CW∞ value of 154.82 mm and K value of 0.53; while the author in [37] in examined *S. tranquebarica* in Segara Anakan obtained CW∞ values of 151.20 mm for male and 155.30 mm for femaleavs well as K values of 0.90 for male and 1.50 for female. The author in [17] argues that the difference in mud crab growth is presumably influenced by the differences in its environmental conditions; e.g. food availability, average water temperatures and salinity contributing to its growth rate.

## 4. Conclusions and recommendations

### *4.1 Conclusions*

Mud crab (*S. tranquebarica*) captured in the estuary of West Segara Anakan are in the sub-adult life stage (70-120 mm carapace width). The carapace width growth of male mud crabis similar to its weight growth, while that of female mud crab is more dominated by carapace width than the weight. In addition, the maximum condition factor of mud crab was obtained in November for male and December for female crab. Asymptotic carapace width (CW∞) for male and female are 190,05 and 163,00, respectively. Growth coefficients (K) for male and female are 0,29 and 0,39, respectively.

### *4.2 Recommendations*

Recommendation on management in reference to the results of this research is to conduct an evaluation of the minimum size of mud crab restricted to be caught based on [31]. This condition is primarily because the size and asymptotic carapace width (CW∞) of the captured individuals obtained in this study do not meet the minimum required size to be captured based on the policy. Moreover, Fishery Management Plan of mud crab is

especially required for *S. tranquebarica* in West Segara Anakan concerning that each species of mud crab in different locations tends to have different bio-ecological characteristics.

Information presented as the outcome of this study requires the support of other sources regarding various life aspects of the mud crab (*S. tranquebarica*) in West Segara Anakan. This is fairly important to support the realization of an optimal and sustainable resource management of mud crab. Therefore, further research on bio-ecological, social and economic aspects that affect the mud crab population in their habitat is necessary.

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