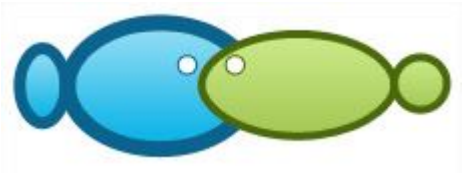

The study of structure and population parameters of mud crab (*Scylla serrata*) on small outer islands in Indonesia (case study: Enggano Island, Bengkulu Province)

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Abstract. Mud crabs occur abundantly in estuaries and mangrove swamp. The Indonesia's Ministry of Marine Affairs and Fisheries allows the capture of this species above 15 cm and 200 g in carapace width and weight, respectively. Furthermore, Enggano Island occurs among the outermost small habitats at approximately 110 miles from the main island. However, no relative form of regulation covers fishing within this territory. The objective of this study is to analyze the size structure, width-weight relationship, growth parameters, mortality and exploitation rates of mud crabs in outer small islands. A random sampling method was used to measure the width and weight of the 467 specimens. Meanwhile, frequency distribution of carapace width and weight, regression analysis, estimations of growth parameters using the von Bertalanffy equation and exploitation mortality rate with the Pauly empirical formula, were also evaluated. The results showed the average values for the carapace width and weight at 14.1 cm and 640 g, respectively. In addition, the growth pattern demonstrated positive and negative allometry for the male and female species, correspondingly. Consequently, a greater growth coefficient was recorded in the females alongside a rapid development to asymptotic length, with a survival rate up to 5. 87 years for females and 6.87 years for males. Furthermore, the natural mortality appears smaller, compared to fishing mortality, with the exploitation rate slightly exceeding the optimal value. This phenomenon indicates an overexploitation of mud crabs on the outer small islands of Indonesia.
Key Words: mud crab, small island, Enggano, carapace, overexploitation.

Introduction. Indonesia reported approximately 6,603,630.6 tons of fish capture in 2019, with a production value of IDR 184,620.3 billion. A total of 1,274,982 tons or 19.3% of the overall output were exported, at a value of US $ 4,641,913,000 or equivalent to Rp. 64,986.78 billion (KKP 2018). Crabs are among the mainstay commodities with a decreased export volume at 8% between 2018 and 2019 (BPS 2019). In retrospect, the volume was 28,091 tons at a value of US $ 414,372,000 or equivalent to IDR 5,801.21 billion in 2014 (KKP 2015).

Crab is one of the leading aquatic supplies in Bengkulu Province, with a decreasing production from 234 tons in 2000 to 55 in 2016 (DKP, Bengkulu Province 2017). The sample is barely obtained in Enggano Island, in the North Bengkulu regency (Cahyadinata et al 2018), comprising the species of *Scylla serrata* (80%), *Scylla tranquebarica* (11%) and *Scylla oceanica* (9%) (Suryani 2006). This region accommodates 52 mud crab fishermen, with welfare category of 2% low, 62% medium and 36% high (Cahyadinata et al 2019a).

Increasing the welfare is achieved by enhancing the quantity of catches, resulting to additional income. Mud crab fishing follows the Minister of Marine Affairs and Fisheries regulation, where a carapace width and weight above 15 cm or 200 g, respectively, are permissible (KKP 2016). Therefore, it is necessary to research the potential resources of the samples.

Studies on population structure and some parameters of mud crab had been done in many areas, such as Indonesia and India. In Indonesia, the research was conducted in Kutai (Wijaya et al 2010), Garut (Avianto et al 2013), Indramayu (Sunarto et al 2015), Bintan Bay (Tahmid et al 2015), Bintuni Bay (Hoek et al 2015), Subang (Kumalah 2017), Bulungan waters (Widigdo et al 2017), Banten Bay (Noviani et al 2020) and Cilacap (Sulistiono et al 2021), while external location was the Chilika lagoon, India (Mohapatra et al 2010). These investigations focused relatively on large island, with no report in the outermost small island. The researchs about mud crab fishermen on the small island that had been done refer to the household welfare (Cahyadinata et al 2019a), food security and multidimensional poverty (Cahyadinata et al 2019b), perception and participation (Cahyadinata et al 2019c) and evaluation of mud crab utilization (Cahyadinata et al 2020).

The Enggano Island occurs among the outermost small islands in Indonesia (Secretariat of the Indonesian Cabinet 2017), with a distance of approximately 110 miles from the main island (BPS Bengkulu Utara 2018). However, no relative supervision in fishing activities involving mud crabs have been reported. The following enquiries are formulated as the research problems: (1) What is the size structure and relationship between carapace size and width of mud crabs from the outer small islands? (2) What are the estimates of population parameters, in terms of sample growth, mortality and exploitation rate? This study is aimed at assessing the relationship between size structure and carapace width of mud crabs in outer small islands. In addition, the parameters of growth, mortality and exploitation rate are also analyzed.

Material and Method

Study site. Enggano Island is one of the administrative sub districts in North Bengkulu Regency comprising 6 villages, including Kaana, Kahyapu, Malakoni, Meok, Apoho and Banjarsari (BPS Bengkulu Utara 2018). However, only 3 occurred as small crab fishermen settlement, termed Kahyapu, Kaana and Banjarsari, and these are located between 102.05o to 102.25o (E) and 5.17o to 5.31o (S) (BPS Bengkulu Utara 2018).

Data collection. The research data is categorized into primary and secondary. Secondary data was obtained from available literature, including related agency/ institution sources, while field input constitutes the primary data, and are obtained by measuring carapace weight and width with digital scales and callipers.

Sampling. The measurement of carapace width and weight of mud crabs lasted 7 months, between August 2018 and February 2019, using random sampling method (Nazir 2014). This process obtained 467 individual specimens that were harvested by fishermen in Enggano Island.

Data analysis

Size structure. The size analysis of the mud crab encompasses carapace width as well as the minimum and maximum body mass (Bonine et al 2008; La Sara 2010). Also, the frequency distribution of the dimensions was analyzed by determining the number of class hoses, class interval width and the individual class frequency (Walpole 1992). Furthermore, the sample length corresponds to the width of the carapace, as body growth influences the increase in carapace width beyond the carapace length (Siahainenia 2008).

Carapace lenght and weight relationship. The weight-length relationship is employed in the analysis of mud crab growth patterns, using regression analysis. This correlation is described in two forms, termed isometric and allometric (Effendie 2006):

$W = aCW^b$ ..... (1)

where: W is individual weight (g), CW is the crab carapace width (cm), a is the intercept (the intersection of the width-weight relationship curve, and b is the width-weight estimator relationship.

The Ln W = Ln a + b Ln CW equation is used to obtain a linear expression, while to derive the parameters a and b, regression analysis is employed. However, with Ln W as Y and Ln CW as X, then the regression equation becomes:

$Y = a + bX$ ..... (2)

In addition, to test the value of b = 3 or b ≠ 3, a t-test (partial test) is conducted with the hypothesis:

H0: b = 3 means the relationship of width to weight is isometric;

H1: b≠3 means the relationship of length and weight is allometric, that is, positive allometric, if b> 3 (weight gain is faster than width gain) and negative allometric if b <3 (width gain is faster than weight gain).

Growth parameters estimation. Growth parameter estimation is conducted, using the von Bertalanffy equation (Sparre & Venema 1999):

$$Lt = L\infty(1 - e^{[-K(t-t0)]}) \quad \text{.....(3)}$$

where: Lt is the length of the crab at age t (time unit), L∞ is the theoretical maximum length (asymptotic), K is the growth coefficient (per unit time), t0 is the theoretical life at zero length. The values of L∞ and K are obtained from the calculation results, using the ELEFAN I method (electronic length frequency analysis). However, to determine the t0 (theoretical age) of crabs at zero carapace width, the empirical equation of Pauly (1983) in Sparre & Venema (1999) is applied as follows:

$$\log(-t0) = 0.392 - 0.275(\log L\infty) - 1.038(\log K) \quad \text{.....(4)}$$

Mortality and exploitation rates estimation. The total mortality rate (Z) and natural mortality (M) were calculated using L∞ and K data. In addition, M is derived using the Pauly (1983) empirical equation in Sparre & Venema (1999) as follows:

$$\text{Log M} = 0.0066 - 0.279 \log L\infty + 0.6543 \text{ Log K} + 0.4634 \text{ Log T} \quad \text{.....(5)}$$

where: T is the surface temperature of water, then the catch mortality rate (F), is obtained using:

$$F = Z - M \text{ or } Z = F + M \quad \text{.....(6)}$$

where: F is the fishing mortality rate (per year), Z is the total mortality rate (per year) and M is the natural mortality rate (per year). The estimated exploitation rate (E) per year is calculated by comparing the fishing mortality (F) to the total mortality (Z) with the Pauly (1984) equation as follows:

$$E = \frac{F}{F+M} \text{ or } E = \frac{F}{Z} \quad \text{.....(7)}$$

The fishing mortality rate (F) or the optimum exploitation rate (E) is optimum F = M and optimum E = 0.5. A value of E > 0.5 indicates the occurrence of overfishing, while E < 0.5 denotes a low exploitation level and E = 0 shows optimal utilization (Sparre & Venema 1999).

Results and Discussion

Size structure. The total samples were 467 crabs (*Scylla serrata*), comprising 249 male (53.32%) and 218 female (46.68%). Also, the minimum and maximum carapace width were 9.4 and 19.7 cm, respectively, with an average of 14.1 cm. Figure 1 shows the male crabs as the optimal frequency between classes 13-13.5 and 14.2-14.7 cm, while the female occurred between 16 and 16.5 cm.

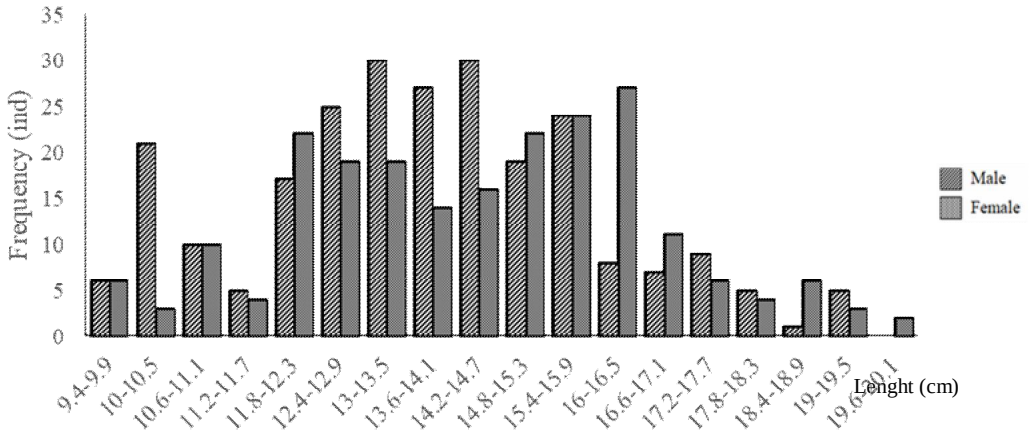


Figure 1. Distribution of frequency distribution of mud crab carapace (*S. serrata*).

The minimum carapace width represents the male, while the maximum is the female. Age groups were analyzed depending on the frequency distribution of carapace width with ELEFAN I, using FiSAT II program. The results showed a growth occurrence with an increase in cohort lines, more denser in the female samples. This shows a rapid development in male, compared to the female (Figures 2 and 3).

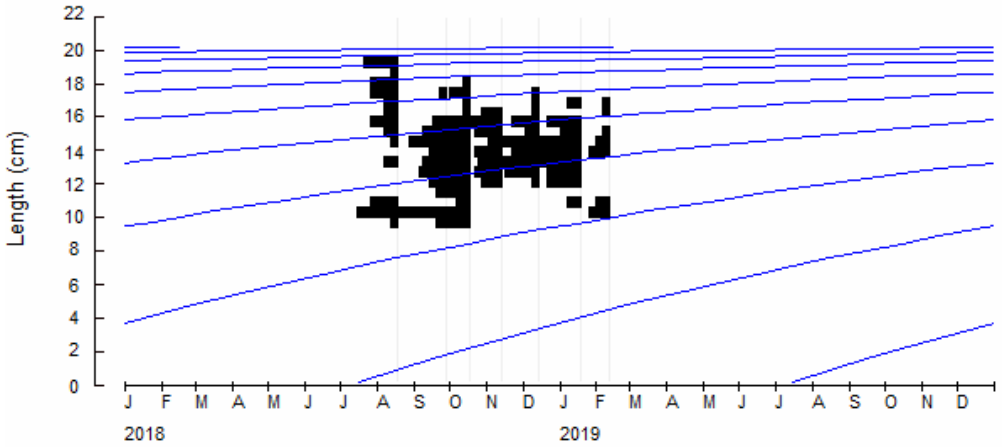


Figure 2. Carapace widths distribution width of male mud crabs based on frequency data using von Bertalanffy plot.

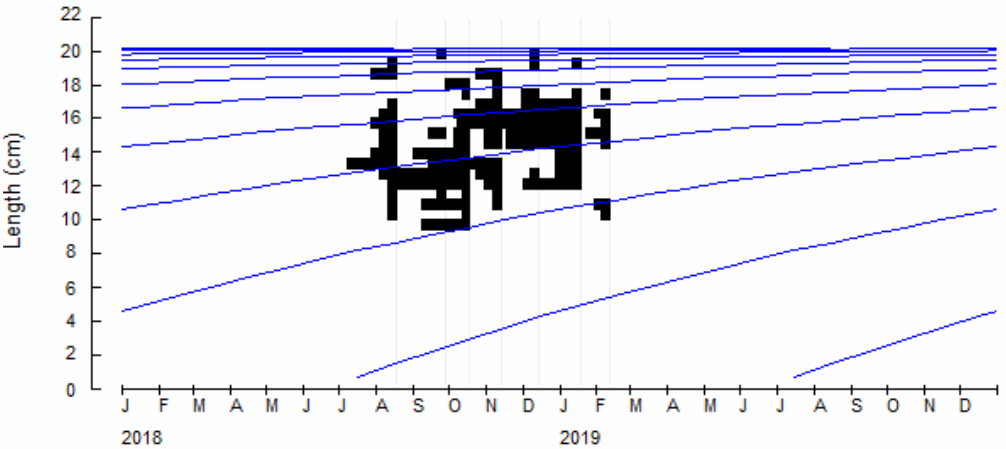


Figure 3. Carapace widths distribution of female mud crabs based on frequency data using the von Bertalanffy plot.

The researches in the Subang (Kumalah 2017) and Kutai (Wijaya et al 2010), also showed relatively small sizes, including males ranging from 5.6 to 12.5 cm and from 5.0 to 15.4 cm while females occurred between 6.2-11.5 cm and 4.5-17.1 cm. However, the species in Bintan tend to be extensive, measuring 6.4-17.2 cm for males and 6.7-16.6 cm for females (Tahmid et al 2015), as well as the carapace width of the Bintuni samples from 8.7 to 15.9 cm and from 8.8 to 15.6, correspondingly (Hoek et al 2015).

Carapace width and weight relationship. The minimum and maximum crab weight are approximately 167 and 1,890 g, respectively, with an average of 640 grams. Figure 4 shows the male crabs at the greatest frequency in the class interval of 550.0-645.6 g, while the females occurred between 358.5 and 454.2 g.

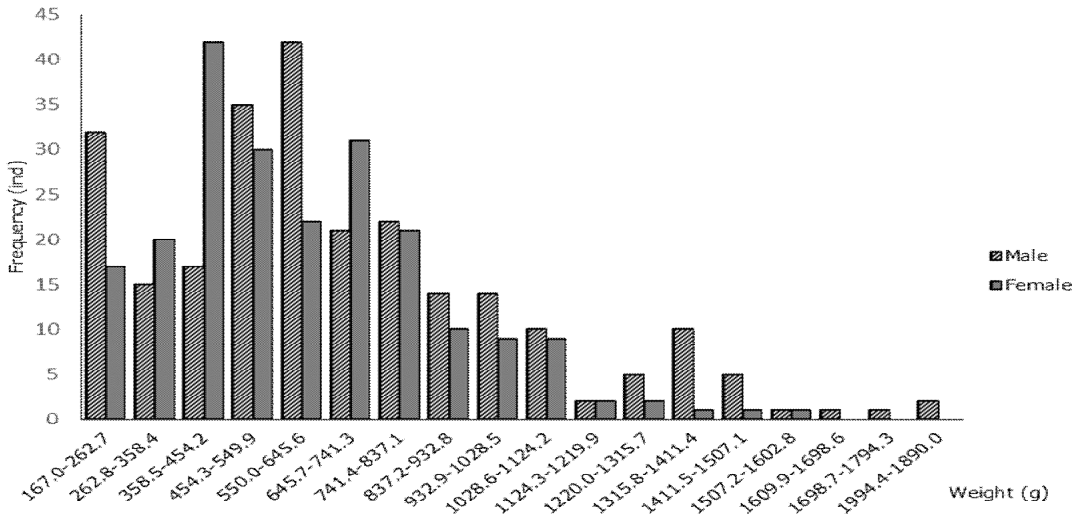


Figure 4. Frequency distribution of mud crab weights (*S. serrata*).

The minimum weight of male crabs is 167 g and the maximum is 1,890 g, with an average of 676.7 g, while the female 180 g and 1,591 g, respectively, with an average of 598.1 g. Figure 5 estimates the correlation between carapace width and weight of the male and female crabs, with determination coefficients of 0.91 and 0.94, respectively. The analysis results are used to determine the growth pattern with the carapace-weight relationship model: $W = 0.1042CW^{3.3053}$ for the male and $W = 0.3414CW^{2.776}$ for female. Furthermore, the t-test results showed that the growth pattern of male crabs was positive allometric, while the female was negative.

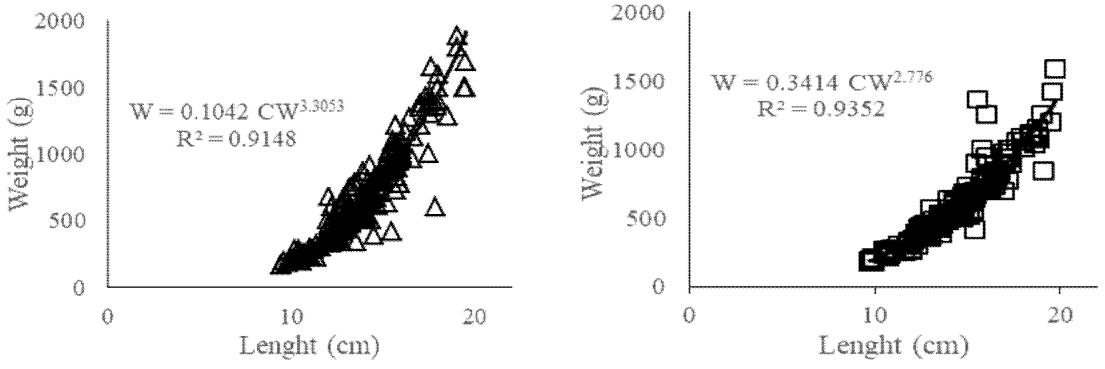


Figure 5. Relationship between carapace width and weight of mud crabs (*S. serrata*): (a) male, and (b) female.

The relationship between carapace width and weight is very important in estimating stock structure (Josileen 2011), developing stock assessment models (Moutopolos & Stergiou 2002) and continuous population evaluation (Sangun et al 2009). Male crabs generally show a positive allometric growth pattern, but negative for the females. This indicates a greater weight gain of male crabs, compared to carapace width expansion.

The female crabs possess a carapace width gain greater than the weight gain. Also, the species with similar carapace width between males and females tends to be heavier (Onyango 2002; Siahainenia 2008; Wijaya et al 2010). Furthermore, adult male mud crabs have a large claw size and are very functional in the reproductive process, due to the ability to firmly hold, pinch, and also turn over the female during copulation (Phelan & Grubert 2007).

Previous crab researches in several Indonesia waters showed that the range of carapace width (CW) did not significantly vary with this investigation. However, the present study observed the larger sizes, compared to other locations, ranging between 9.4 and 19.5 cm for the male samples and 9.4-20.10 cm for the female. The smallest size range was obtained from a research in the Bulungan area (North Kalimantan) for male and female crabs between 4.0-8.9 cm and 3.2-9.1 cm, respectively (Widigdo et al 2017).

Growth parameters. The growth parameters are estimated using several values, including asymptotic length (L∞), growth coefficient (K), and theoretical age with zero carapace width (t_0). Table 1 represents the calculation results of the growth parameters, while Figure 6 and Figure 7 visualizes the growth curve.

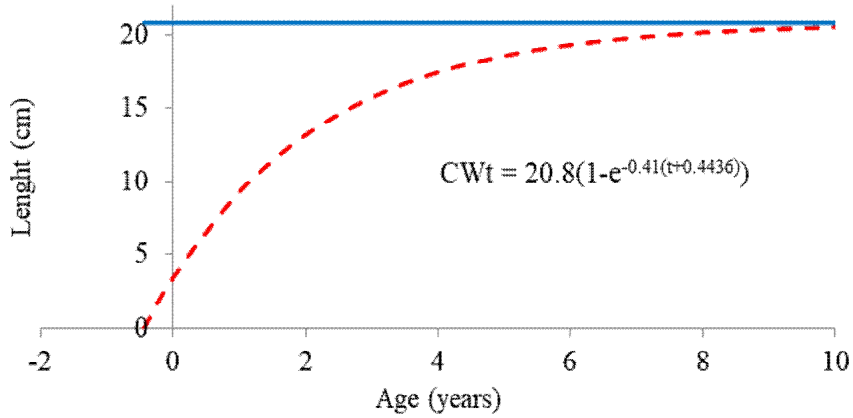


Figure 6. Relationship between age and carapace width of male crabs (*S. serrata*) based on the von Bertalanffy equation.

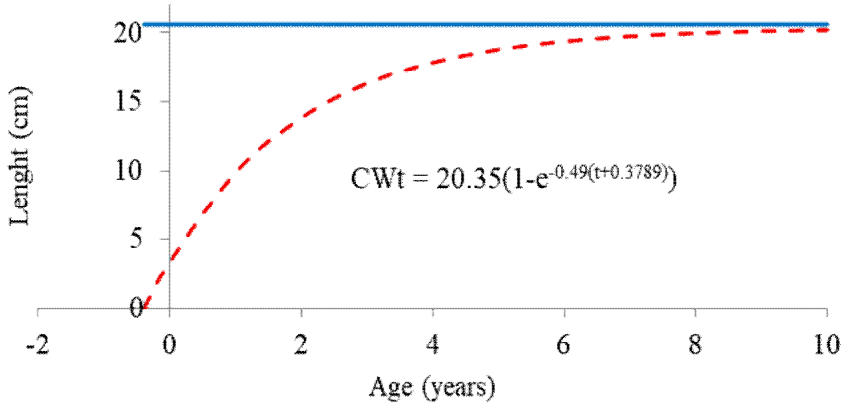


Figure 7. Relationship between age and carapace width of female crabs (*S. serrata*) according to the von Bertalanffy equation.

Table 1

Results of calculation of growth parameters for mud crabs

Growth parameters	*Male*	*Female*
K (per year)	0.41	0.49
L_∞ (cm)	20.80	20.35
t_0 (year)	-0.4436	-0.3789
Life span (year)	6.87	5.87

The research on the growth patterns of mud crab was conducted in several Indonesian waters and beyond. The research locations include Kutai, Bintan Bay, Bintuni Bay, Subang and Bulungan waters as well as India (Table 2).

Table 2

Growth patterns of mud crab *(Scylla serrata*) in several Indonesian and Indian waters

No	*Location*	*Gender*	*b*	*Description*
1.	Kutai waters	Male	3.3930	Positive allometric
	(Wijaya et al 2010)	Female	2.6090	Negative allometric
2.	Bintan Bay	Male	3.2724	Positive allometric
	(Tahmid et al 2015)	Female	2.8711	Negative allometric
3.	Bintuni Bay	Male	3.5100	Positive allometric
	(Hoek et al 2015)	Female	2.6000	Negative allometric
4.	Subang waters	Male	3.1600	Positive allometric
	(Kumalah 2017)	Female	2.2600	Negative allometric
5.	Bulungan waters	Male	3.1012	Positive allometric
	(Widigdo et al 2017)	Female	2.3968	Negative allometric
6.	Chilika Lagoon, India	Male	3.2150	Positive allometric
	(Mohapatra et al 2010)	Female	2.7510	Negative allometric

The growth pattern of crabs on Enggano Island showed similar pattern with several studies (Wijaya et al 2010; Mohapatra et al 2010; Tahmid et al 2015; Hoek et al 2015; Kumalah 2017; Widigdo et al 2017). However, the growth coefficient of female crabs was greater, compared to the male, resulting to a faster asymptotic length. Conversely, the growth coefficient of male crabs appears smaller than the female, leading to a gradual asymptotic length. Also, the growth equations for male and female species based on the von Bertalanffy model are $CWt = 20.8\ (1\text{-}e^{-0.41\ (t\ +\ 0.4436)})$ and $CWt = 20.35\ (1\text{-}e^{-0.48\ (t\ +\ 0),\ 3947)})$, respectively. Furthermore, female crabs are estimated to survive up to 5.87 years, while the male extends to 6.87.

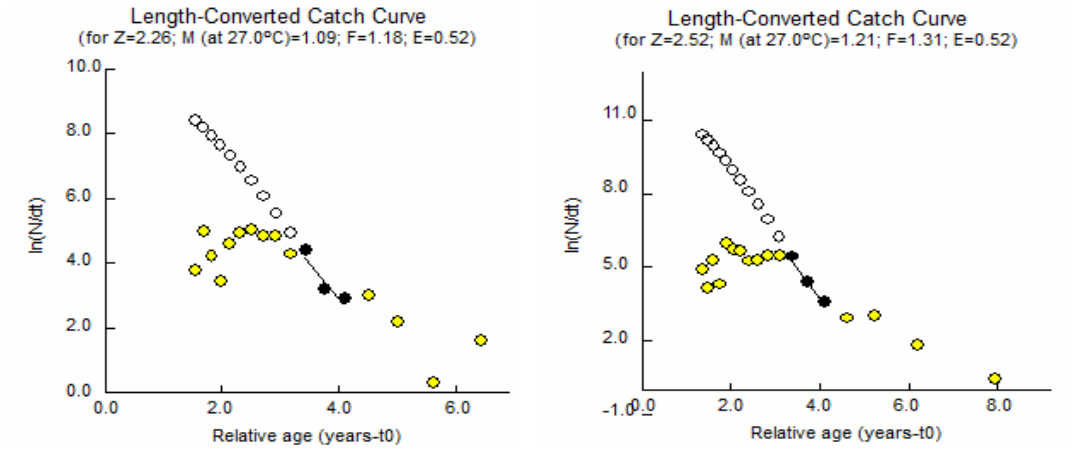
Growth is defined as changes in the length and weight of an organism at a certain time (Effendi 1979). The ELEFAN I method is used to estimate and analyze several growth parameters, including asymptotic width (L∞), growth coefficient (K), and theoretical age with zero crab carapace width (t0). The analysis showed that the asymptotic width and growth coefficient (K) of female mud crabs were higher, compared to the male. These values indicate the male achieves L∞ faster than the female. Higher growth coefficient (K) of a species reflects a faster duration to reach the asymptotic length (Sparre & Venema 1999). Several studies on the growth of small crabs exist with less varying values, although the L∞ also appears minimal, compared to the present research. Furthermore, the asymptotic widths of males and females are estimated at 17.69 and 16.96 cm respectively in Bintan (Tahmid et al 2015), 18.08 and 16.6 cm in Subang (Kumalah 2017), and 15.91 and 15.70 cm in Kutai waters (Wijaya et al 2010).

In Enggano Island and in other locations, the growth coefficients for female crabs were greater, compared to the male (Wijaya et al 2010, Tahmid et al 2015; Kumalah 2017). The difference in carapace width growth is influenced by internal and external factors. Internal factors are generally complex to control, and include gender, age, heredity and disease. According to Effendie (2006), the main external factors

contributing to fish growth are food and temperature. However, growth is influenced by several parameters, including temperature, food and density (Morgan 1980).

Life expectancy-value or lifespan is the age when the carapace width achieves 95% of the asymptotic width (CW_∞). In this research, the value is based on Taylor (1958) in Pauly (1984). The life expectancy value of crabs is estimated depending on the values of K and t0. This research shows that the life expectancy of crabs ranges from 6 to 7 years, and is lower for the female species. Furthermore, Tahmid et al (2015) reported a life expectancy between 7 and 8 years in Bintan, while Wijaya et al (2010) obtained an estimated lifespan between 3 and 6 years in Kutai waters.

Mortality and the exploitation rate. Figure 8 represents the analysis results of the total (Z), natural (M), fishing (F) mortalities, as well as the exploitation rate (E) in male and female crabs. The natural mortality value for both species appears minimal, compared to the mortality arrest. This value indicates the death of crabs is caused by fishing factors. However, the exploitation rate (E) for male and female samples both obtained 0.52 and were above the optimum values.



(a) (b)

Figure 8. Graph of natural mortality (M), fishing mortality (F), total mortality (Z), and exploitation rate (E) of crabs (*S. serrata*): (a) male, and (b) female.

The total mortality rate (Z) is the sum of the fishing (F) and natural mortality (M) rates (King 1995). Natural mortality is death caused by predation, spawning stress, starvation, disease, and old age (Sparre & Venema 1999). However, certain environmental factors also influence the natural mortality, including mean water temperature, maximum length ($L\infty$), and growth rate (K) (Pauly (1980) in Sparre & Venema (1999)). The total mortality appears greater in female crabs, indicating more susceptibility to death, compared to the male. The fishing mortality rates (F) of male and female are higher than the natural mortality rate. Furthermore, the exploitation of crabs in nature has increased alongside an intense pressure on mangrove ecosystems (Mirera 2011). This circumstance threatens the sustainability, therefore, effective management appears very necessary.

The exploitation rate value is defined as the ratio between the fishing and the total mortality rates. In both species, the exploitation rate value is 0.52 per year. Also, the resource exploitation obtained an optimal value of 0.50 (Gulland (1971) in Pauly (1984)). Furthermore, the research results showed the exploitation rate of male and female crabs slightly surpasses the optimal exploitation value or exceeds 0.5. This denotes overexploitation on the mud crabsin Enggano Island.

Conclusions. Based on results and discussion, the carapace width of mud crabs ranges from 9.4 to 19.7 cm, with an average of 14.1 cm, while the weight occurs between 167 and 1,890 g, with an average of 640 g. The relationship between both variables shows positive allometric for the male crabs, in terms of growth pattern, while the females are negative allometric. Also, the growth coefficient of female crabs appears greater

compared to males, indicating rapid attainment of asymptotic length, with an estimated survival rate up to 5.87 years, while the male records 6.87 years. Furthermore, the natural mortality of crabs is smaller than fishing mortality, with the exploitation rate slightly exceeding the optimal value. This phenomenon denotes overexploitation of mud crabs on the outer small islands in Indonesia.

The results showed that fishermen continue to capture mud crab with a carapace width ≤ 15 cm or weighing ≤ 200 g, indicating symptoms of over-exploitation. Therefore, it is necessary to enforce fishing rules by strengthening fisheries management institutions in the outermost small islands in Indonesia.

References

Avianto I., Sulistiono, Setyobudiandi I., 2013 [Habitat characteristics and potency of mud crabs *Scylla serrata*, *S. transquaberica*, and *S. olivacea* in Cibako Mangrove Forest, Garut District, West Java]. Bonorowo Wetlands 3(2):55-72. [in Indonesian]

Bonine K. M., Bjorkstedt E. P., Ewel K. C., Palik M., 2008 Population characteristics of the mangrove crab *Scylla serrata* (Decapoda: Portunidae) in Kosrae, Federated States of Micronesia: effects of harvest and implications for management. Pacific Science 62(1):1-19.

[BPS] Badan Pusat Statistik, 2019 [Bulletin of foreign trade export statistics by commodity group and country]. Badan Pusat Statistik, Jakarta, 232 pp. [in Indonesian]

[BPS] Badan Pusat Statistik Bengkulu Utara, 2018 [Enggano District in figures]. Badan Pusat Statistik Bengkulu Utara, Argamakmur, 60 pp. [in Indonesian] Cahyadinata I., Fahrudin A., Sulistiono, Kurnia R., 2018 [Potency of catch fisheries development on small outer island (case study in Enggano Island, Bengkulu Province)]. Jurnal Agrisep 17(2):151-162. [in Indonesian]

Cahyadinata I., Fahrudin A., Sulistiono, Kurnia R., 2018 [Potency of catch fisheries development on small outer island (case study in Enggano Island, Bengkulu Province)]. Jurnal Agrisep 17(2):151-162. [in Indonesian]

Cahyadinata I., Fahrudin A., Sulistiono, Kurnia R., 2019a Household welfare of mud crab fishermen in small outermost islands. Case study: Enggano Island, Bengkulu Province, Indonesia. AACL Bioflux 12(2):564-574.

Cahyadinata I., Fahrudin A., Sulistiono, Kurnia R., 2019b Food security and multidimensional poverty of mud crab fishermen household in small and outer islands of Indonesia. Case study: Enggano Island, Bengkulu Province. AACL Bioflux 12(4):1196-1207.

Cahyadinata I., Fahrudin A., Kurnia R., Sulistiono, 2019c Perception and participation of fishermen in the sustainable management of mud crabs on the outermost small Island (Case study: Enggano Island, Bengkulu Province, Indonesia). International Journal on Advanced Science, Engineering and Information Technology 9(4):1330-1336.

Cahyadinata I., Fahrudin A., Sulistiono, Kurnia R., 2020 Evaluation of mud crab utilization in the small outermost island: A case study of Enggano Island, Bengkulu Province, Indonesia. IOP Conference Series: Earth and Environmental Science 420:012008.

[DKP] Dinas Kelautan dan Perikanan Provinsi Bengkulu., 2017 [Bengkulu Province capture fisheries statistics]. Bengkulu, 95 pp. [in Indonesian]

Effendie M.I., 1979 [Fishery biology]. Yayasan Pustaka Nusatama, Yogyakarta, 112 pp. [in Indonesian]

Effendie M.I., 2006 [Fishery biology]. Yayasan Pustaka Nusatama. Yogyakarta, 163 pp. [in Indonesian].

Hoek F., Razak A. D., Sururi M., Yampapi M., 2015 [Frequency distribution of carapace width and weight of mud crab (*Scylla serrataforskal*) with folding trap fishing gear in the waters of Bintuni Bay Regency, West Papua]. Jurnal Airaha 4(2):57-64. [in Indonesian]

Josileen J., 2011 Morphometrics and length-weight relationship in the blue swimmer crab, *Portunus pelagicus* (Linnaeus, 1758) (Decapoda, Brachyura) from the Mandapam Coast, India. Crustaceana 84(14):1665-1681.
King M., 1995 Fisheries biology, assessment, and management. Wiley, 341 pp.
[KKP] Kementerian Kelautan dan Perikanan, 2015 [Volume and value of fishery products exports by main commodity]. Jakarta, 56 pp. [in Indonesian]
[KKP] Kementerian Kelautan dan Perikanan, 2016 [Regulation of the Minister of Maritime Affairs and Fisheries of the Republic of Indonesia Number 56/Permen-Kp/2016 concerning the prohibition of catching and/or releasing lobster (*Panulirus* spp.), crab (*Scylla* spp.), and swimming crab (*Portunus* spp.) from the territory of the Republic of Indonesia]. Kementerian Kelautan dan Perikanan, Jakarta, 8 pp. [in Indonesian]
[KKP] Kementerian Kelautan dan Perikanan, 2018 [Marine and fisheries in figures for 2017]. Jakarta, 212 pp. [in Indonesian]
Kumalah A. A., 2017 [Sustainability status of mangrove crab (*Scylla serrata* - Forsskal, 1775) resource management in the mangrove ecosystem of Subang Regency, West Java]. MSc thesis, Bogor (ID): IPB University, 91 pp. [in Indonesian]
La Sara, 2010 Study on the size structure and population parameters of mud crab *Scylla serrata* in Lawele Bay, Southeast Sulawesi, Indonesia. Journal of Coastal Development 13(2):133-147.
Mirera O. D., 2011 Trends in exploitation, development and management of artisanal mud crab (*Scylla serrata*-Forsskal-1775) fishery and small-scale culture in Kenya: an overview. Ocean and Coastal Management 54(11):844-855.
Mohapatra A., Mohanty R. K., Mohanty S. K., Dey S., 2010 Carapace width and weight relationships, condition factor, relative condition factor and gonado-somatic index (GSI) of mud crabs (*Scylla* spp.) from Chilika Lagoon, India. Indian Journal of Marine Sciences 39(1):120-127.
Morgan G. R., 1980 Population dynamics of spiny lobster. In: The biology and management of lobster II. Cobb J. S., Phillips B. F. (eds), Academic Press, New York, pp. 189-217.
Moutopoulos D. K., Stergiou K. I., 2002 Length-weight and length-length relationships of fish species from the Aegean Sea (Greece). Journal of Applied Ichthyology 18(3):200-203.
Nazir M., 2014 [Research methods]. Penerbit Ghalia Indonesia, 486 pp. [in Indonesian]
Noviani E., Sulistiono, Samosir A. M., 2020 Heavy metal (Pb, Hg) extent in mud crab (*Scylla serrata*) in Cengkok Coastal Waters, Banten Bay, Indonesia. Omni-Akuatika 16(2):108-115.
Onyango S. D., 2002 The breeding cycle of *Scylla serrata* (Forskal, 1755) at Ramisi River estuary, Kenya. Wetlands Ecology and Management 10:257-263.
Pauly D., 1984 Fish population dynamics in tropical waters: a manual for use with programmable calculators. Manila: ICLARM, 325 pp.
Phelan M., Grubert M., 2007 The life cycle of the mud crab. Fishnote No: 11. Coastal Research Unit, Department of Primary Industry, Fisheries and Mines. Northern Territory Government of Australia, Darwin, 4 pp.
Sangun L., Tureli C., Akamca E., Duysak O., 2009 Width/length-weight and width-length relationships for 8 crab species from the north-eastern Mediterranean coast of Turkey. Journal of Animal and Veterinary Advances 8(1):75-79.
Sekretariat Kabinet RI., 2017 [Presidential Decree of the Republic of Indonesia Number 6 of 2017 concerning Designation of Outermost Small Islands]. Sekretariat Kabinet RI., Jakarta, 18 pp. [in Indonesian]
Siahainenia L., 2008 [Bioecology of mangrove crabs (*Scylla* spp.) in the mangrove ecosystem of Subang Regency, West Java]. PhD thesis, Bogor (ID): IPB University, 246 pp. [in Indonesian]
Sparre P., Venema S. C., 1999 [Introduction to the study of tropical fish stocks]. Food Organization, United Nations Cooperation with Fisheries Research and Development Center, Agricultural Research and Development Agency]. Jakarta, 438 pp. [in Indonesian]

Sunarto, Sulistiono, Setyobudiandi I., 2015 [Relationship of mud crab (*Scylla* spp.) with mangrove and substrate in silvofishery ponds, Eretan, Indramayu]. Marine Fisheries 6(1):59-68. [in Indonesian]
Sulistiono, Yahya N. M., Riani E., 2021 [Distribution of *Scylla* spp. in estuarine of Donan River, Eastern Segara Anakan, Cilacap]. Habitus Aqua 2(1):1-11. [in Indonesian]
Suryani M., 2006 [Ecology of mangrove crab (*Scylla Serrata Forskal*) in the mangrove ecosystem on Enggano Island, Bengkulu Province]. MSc thesis. Semarang (ID): Universitas Diponegoro, 91 pp. [in Indonesian]
Tahmid M., Fahrudin A., Wardiatno Y., 2015 [Study of size structure and population mud crab (*Scylla serrata*) in the mangrove ecosystem of Bintan Bay, Riau Islands]. Jurnal Biologi Tropis 5(2):93-106. [in Indonesian]
Walpole R. E., 1992 [Introduction to statistics]. Penerbit Gramedia Pustaka Utama, Jakarta, 515 pp. [in Indonesian]
Widigdo B., Rukisah, Laga A., Hakim A. A., Wardiatno Y., 2017 Carapace length-weight and width-weight relationships of *Scylla serrata* in Bulungan District, North Kalimantan, Indonesia. BIODIVERSITAS 18(4):1316-1323.
Wijaya N. I., Yulianda F., Boer M., Juwana S., 2010 [Population biology of mangrove crab (*Scylla serrata* F.) in the mangrove habitat of Kutai National Park, East Kutai Regency]. Oseanologi dan Limnologi di Indonesia 36(3):443-461. [in Indonesian]

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