Growth analysis, mortality and exploitation level of Mud Crab *Scylla serrata*, Forskål 1775, (Malacostraca : Portunidae) in Mangkang Wetan waters, Semarang, Central Java, Indonesia

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Abstract

Awareness of Mud Crab over exploitation in Mangkang Wetan Waters has been noticed. One of the reference information is the growth study to determine the condition of the mud crab population. High demand encourages the fisherman to catch more, which leads to overexploitation in nature. The study aimed to estimate the growth, mortality, and exploitation rate of mud crabs. The 921 mud crabs samples were collected from Mangkang Wetan Waters from October 2018 to January 2019. The method used was the survey method. The crabs were taken once a week for 4 months. The width and weight of crab carapace were measured. The growth rate of S. serrata was 0.93/year (male) and 0.69/year (female). The natural mortality rate of S. serrata was 1.08/year (male) and 0.89/year (female), the mortality of catch (F) was 0.55/year (male) and 1.09/year (female). The rate of exploitation of male S. serrata reached 34%, and the rate of exploitation of female S. serrata was 55%. The exploitation of female S. serrata shows that overexploitation has occurred because the optimum value of exploitation (E-OPTIMUM) is equivalent to E=50%.

Keywords: Growth; Mortality; Exploitation; *Scylla serrata*

INTRODUCTION

Mud crabs (*S. serrata*) are widely distributed throughout the Indo-West-Pacific region (IWP) and are often associated with mangrove forests (Butcher *et al.*, 2012; Hubatsch *et al.*, 2015; Viswanathan *et al.*, 2016). *S. serrata* has a high economic value in both domestic and international markets (Moksnes *et al.*, 2014; Hubatsch *et al.*, 2015). *S. serrata* can live out of the water area up to five days so, that, these crabs are suitable for long distant delivery (Atagholipour *et al.*, 2013). Nowadays, mud crabs play an important role in Asia, especially the Indonesian economy. This due to the generating of significant income to the coastal communities and small-scale fisheries

(Meynecke *et al.*, 2012; Atagholipour *et al.*, 2013). The efforts to capture *S. serrata* have increased dramatically in recent decades in many countries including Asia (Hubatsch *et al.*, 2015; Viswanathan *et al.*, 2016). Mangkang Wetan is a district with the highest mangrove area (6.51 ha) in Semarang City. The mangrove ecosystem had huge historical damage, resulted in bad coastal abration. The mangrove replantation was executed and the condition turned better. This mangrove recovery leads this area to be the best Mudcrab production in Semarang city.

Nowadays, the consumers' needs are still fulfilled from the catches in nature. Moreover, this will leads to over-exploitation and threatens the crab population (Hubatsch

et al., 2014). The fishermen will catch the smaller *S. serrata*. As a consequence of this, *S. serrata* has no opportunity to grow and reproduce well (Meynecke and Richards, 2014; Viswanathan *et al.*, 2016). The catch of mud crabs in Indonesian territory has been regulated by Permen KP No. 56 / PERMEN-KP / 2016 which states that the capture of mud crab is permitted when the carapace width is up to 15 cm or above 200 grams.

S. serrata commonly live in muddy ground and water. This area provides a lot of food and avoids predation risk (Hubatsch *et al.*, 2014; Sara *et al.*, 2014). The juvenile's nature moves from subtidal to an intertidal area with sandy substrates. The juvenile crabs become an easy target for predators because they cannot hide quickly in the sand as on muddy substrates (Hubatsch *et al.*, 2014). *S. serrata* females migrate to lay eggs towards the sea and can be found in waters within up to 80 km offshore (Sara *et al.*, 2014). Female *S. serrata* seeks habitats whose abiotic conditions are stable with high salinity and temperature to incubate larvae. Stable environments are chosen because they can maximize the survival rate ability of their larvae (Hubatsch *et al.*, 2015).

There are some researches have been done on the growth of mud crabs in the same area, such as research concerning the biomorphometry of Mud crab Hardiyanti *et al.* (2018). Research has been conducted by Moksnes *et al.* (2014) in East Africa, Amarasekara *et al.*, (2016) in Sri Lanka, and Gonzales *et al.*, (2018) in the Philippines. Whereas in Indonesia, similar research was conducted by Sara (2010) in Lawele Bay, Tetelpta *et al.* (2017) in West Seram, and Suman *et al.* (2018) in Kendari Bay. Study related to the same classes Malacostraca (*Portunus pelagicus)* in northern part of Java Sea were also reported by Maghfirani *et al.* (2019), Wibowo *et al.* (2019) in Rembang waters. Futhermore Anam *et al.* (2019) and Putra *et al.* (2019) were studied the similar species in different coastal area, Demak waters. Moreover, in Jepara waters, the similar species were also been investigated by Rizkasumarta *et al.* (2019) and Hidayah *et al.* (2019). Most researchers agree that recently,

crab size becomes smaller due to the ecosystem imbalance.

S. serrata is a common species caught in Mangkang Wetan waters. As the market demand continues to increase, *S. serrata*'s capture is intensified and this might affect the abundant and size distribution of the local crab population. Based on this study, some information is needed regarding the growth and mortality of *S. serrata* in Mangkang Wetan Village by determining population growth and mortality rates, rate of exploitation of male and female crabs so that can be useful information for the guidelines in managing crab resources in Mangkang Wetan Village, in the future.

MATERIALS AND METHODS

The study area was depicted in Figure 1. Point 1,2,3,4,5 is a pond area, close to the mangrove forest which is the natural habitat of mangrove crabs. Point 3 and Point 4 are pond areas near the beach where crabs will pass through this area when they migrate to the sea or return to the mangrove forest area.

Mud crab samples were obtained from five different stations and five fishermen. Soon as crabs landed, all 921 crabs were measured and identified. It was the measurements of crabs total weight and carapace width both in male and female crabs. Sampling was carried out 16 times, every week for 4 months (October 2018 – January 2019). The area was depicted in the research location map in Figure 1.

Identification, Width and Weight Samples Measurements

Identification of the mud crabs by morphology was done using the Book of Identification Mud Crab / *Scylla* spp. (Keenan *et al.*, 1998; Ministry of Maritime Affairs and Fisheries, 2016). The carapace length (CL) and width (CW) (Figure 2.) were measured using calipers with 0.01 mm inaccuracy. Bodyweight (BW) was weighed by the analytic balance in 0.1 g accuracy. The identification of male and female crabs was done by observation on crabs abdomen.
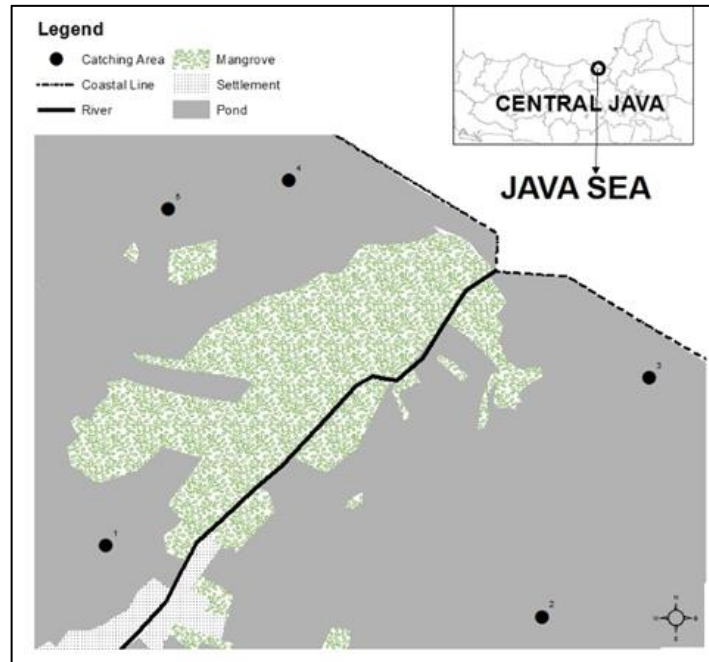
Figure 1. Map of Mangkang Wetan Waters, Semarang, Central Java, Indonesia.
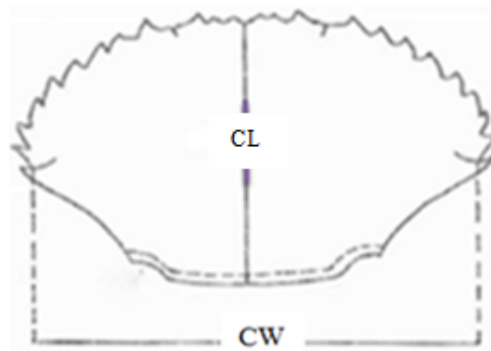
Figure 2. Crab Measurements (CW = Crab Width, CL = Crab Length)(Overton *et al*., 1997)
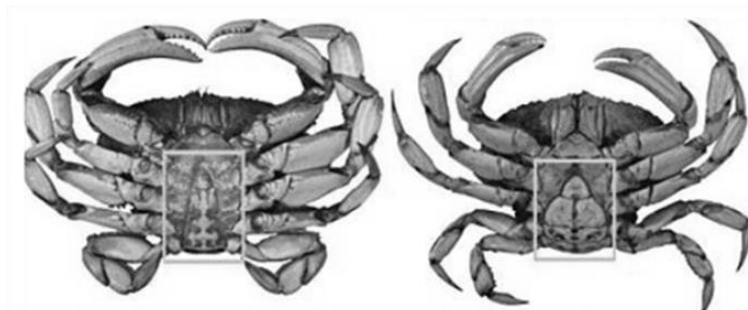
Figure 3. The morphological differences between Male (left) and Female (right) crab
Source : (Ministry of Maritime Affairs and Fisheries, 2016)

Analysis on the Relationship of Carapace Width and Weight : Based on Tetelpta *et al*. (2017), data analysis of crab growth patterns can be identified through the relationship between carapace width and body weight.

The value of b is then used to determine the growth pattern, namely isometric growth (b = 3) or allometric growth (b ≠ 3). The relationship between carapace width and weight based on Sparre and Venema (1992).

Von Bertallanffy's Model Growth Parameter Analysis : Based on Amarasekara et al., (2016), the estimation of crab growth uses the formula proposed by Von Bertalanffy. The value of L∞ dan K determined using ELEFAN I incorporated in FiSAT software.

Mortality Analysis and The Rate of Exploitation : According to Amarasekara *et al.*, (2016), natural mortality (M) is assumed by Pauly (1980). According to Amarasekara *et al.*, (2016), estimation of total mortality (Z). (Z) is carried out using the length converted catch curve in the FiSAT program package. Mortality arrest (F) and the rate of exploitation are calculated by the formula Pauly (1983):

RESULTS AND DISCUSSION

A total of 921 crabs (496 males and 425 females) were obtained from October 2018 to January 2019. Data on the width of the carapace were divided into 11 classes, with a 9.4 mm interval class. The lowest carapace width is 52 mm and the highest carapace width is 156.4 mm. All frequency distribution data can be seen in Figure 4. The distribution frequency of male and female crabs in October 2018 was similar. The dominated carapace width was 80.5-99.4 mm. In November 2018, the number of male crabs

was higher and the carapace was wider (109 –127.9 mm) compared to the female. In December 2018 and December 2019 the number of male crabs was higher but dominated in smaller carapace width (71– 80.4 mm).

Only 28.2% of *S. serrata* males and 20.24% of females were permitted caught (BW > 200 g). during the study. Based on the unpermitted CW (15 cm), the male crabs catch were 99.6%. While the female crabs catch were 99.53%. The data can be seen in Figure 5.

The analysis of the relationship of carapace width–body weight was determined to find out the growth patterns of *S. serrata*. The results of the analysis can be seen in Table 1. The results show that the relationship between carapace width and crab weight is strong and positive. The increase of carapace width is in relation to the crab weight. The value of b on *S. serrata* is 2.522 (males) and 2.096 (females) (b<3).

Growth Parameters of *Scylla serrata*

The estimation of *S. serrata* growth parameters in this study used the Von Bertalanffy equation. The equation shows that
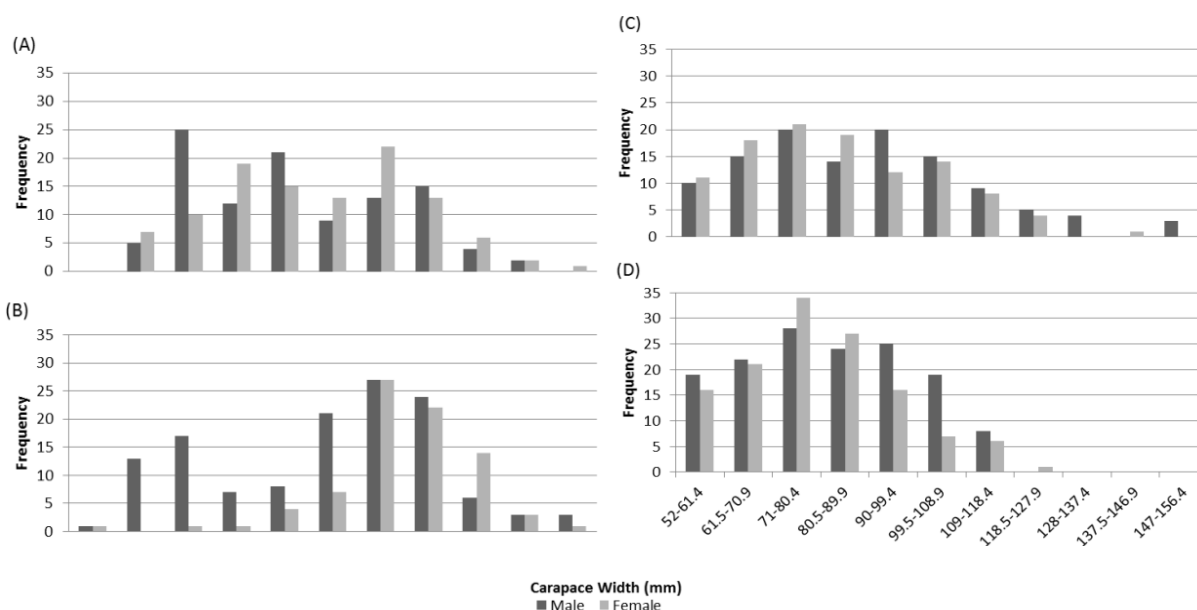
Figure 4. Frequency Distribution of Carapace Width for Male and Female. October (A), November (B), December (C), and January (D)

male CW$_\infty$ (156.03 mm) has slightly lower value when compared to the female (157.87 mm). In contrast, the growth male coefficient of male crabs were higher (0.93.yr^{-1}) compare to the female (0.69.yr^{-1}). The results can be seen in **Table 2.** and **Figure 6.**

Mortality and Explotation Rate of *Scylla serrata*

Total mortality in female crabs was higher (1.98. yr^{-1}) when compared to the male (1.63. yr^{-1}). The natural mortality of male crab using the Pauly empirical equation (temperature = 28.4°C) is 1.08. yr^{-1}. While in female was 1.09. yr^{-1}). Furthermore, the catching mortality and exploitation rate of

female crab was higher than male crabs. Results on the analysis of the estimated mortality and exploitation rate are presented in Table 3.

Based on the results, the frequency distribution of carapace width (CW) of crab males and females were showed that the average width of a carapace in November is the highest. The high value of carapace width in November is thought to be the peak of *S. serrata* reproduction and molting in the waters of Mangkang Wetan. According to Hubatsch *et al*. (2015), *S. serrata* males begin to mature genitally when carapace width ranged is reached from 92 - 110 mm, while
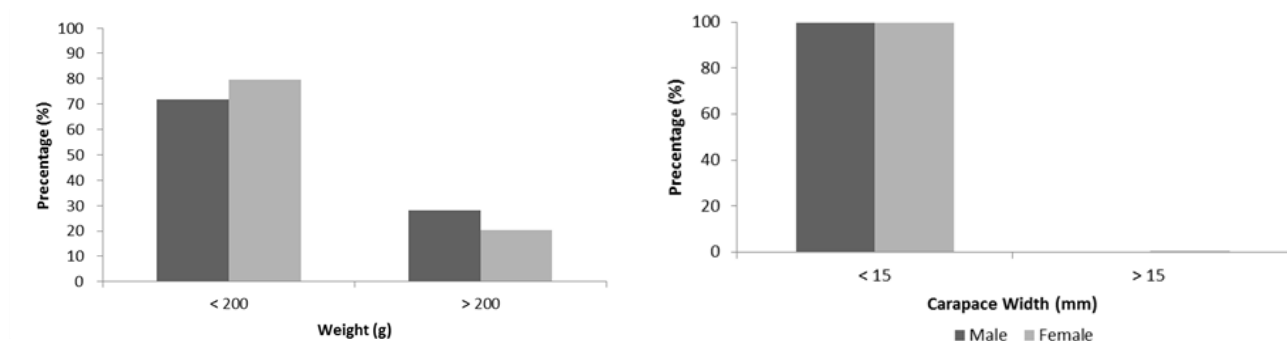
Figure 5. Frequency and Weight Distribution of Male (Black) and Female (Grey) *S. serrata* Carapace and Weight based on Size Permitted Regulation for Trading (Permen KP No. 56 / PERMEN-KP / 2016)
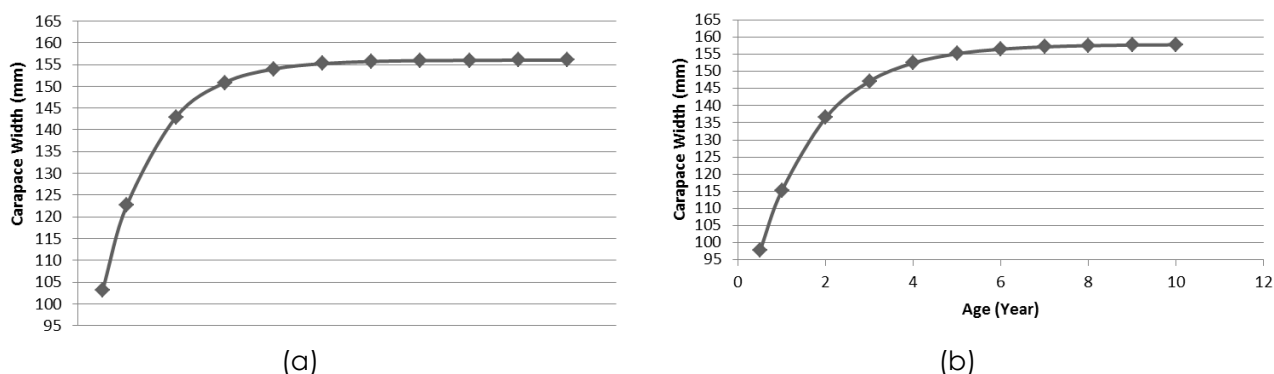
Figure 6. Von Bertalanffy's Growth Curve based on Carapace Width of *S. serrata* Males (A) and Females (B)

Table 1. Relationship of carapace width (CW) with Body weight (BW) of *S. serrata*

Male/Female	W = aL^b	r	R^2
Male	W = 0.00148 L $^{2.522}$	0.926	0.885
Female	W = 0.00942 L $^{2.096}$	0.943	0.891

Table 2. Growth Parameters of *Scylla serrata*

Male/Female	CW$_\infty$ (mm)	K (year^{-1})	t$_0$ (year)	Growth Equation
Male	156.03	0.93	-0.662	CW$_t$ = 156.03 $(1 - e^{-0.93(t+0.662)})$
Female	157.87	0.69	-0.898	CW$_t$ = 157.87 $(1 - e^{-0.69(t+0.898)})$

Table 3. Mortality and Explotation Rate of *Scylla serrata*

Male/Female	Z (year^{-1})	M (year^{-1})	F (year^{-1})	E
Male	1.63	1.08	0.55	0.34
Female	1.98	0.89	1.09	0.55

Denoted: Z = Total mortality; M = Natural mortality; F = Catching mortality; E = Rate of exploitation

the females begin to gonadally mature at an average size of 80 - 120 mm. Supporting this data, in *S. paramamosain* from August to January, according to the increment in carapace width (CW), Fahzan *et al.* (2017) reports that those months are a growth and molting periods.

November is a rainy season. On the other hand, crabs spawning time occurs during the rainy season. Temperature and salinity in the rainy season are suitable for the crab larvae's survival. Data in this observation is supported since the temperature was 25.2 – 29.1°C, and salinity was 15 – 30‰. In December and January, the catch of S. serrata tends to be smaller in size. This indicated that the mating period had occurred in the previous month. Therefore, in December and January, the S. serrata captured was dominated by the small size. The fishermen catch all the mud crabs, whether they were worthy and permitted to be caught or not. These would be sold to the traders. If this continuously happens, the restocking process in nature will be disrupted and slowly but surely, Mud crab will be the extinction species in the future.

The growth patterns of male and female *S. serrata* in Mangkang Wetan waters are negative allometric (b<3). This is also expressed that the increment of crab carapace width is faster than the weight increment. The results of this study are in agreement with research by Tetelpta *et al.* (2017) and Suman *et al.* (2018) in Indonesia as well as Atagholipour *et al.* (2013) in Oman that the growth pattern of *S. serrata* is negative allometric.

The value of b in *S. serrata* males is higher than in females, which has also been observed for *S. tranquebarica* in the Philippines for males (3.3407) and females (2.721) (Gonzales *et al.*, 2018) and *S. olivacea* in India for males (3.035) and females (2.903) (Viswanathan *et al.*, 2016). This due to the fact that male crabs have a higher body weight when compared to the female crabs even though the carapace width is similar (Viswanathan *et al.*, 2016). Moksnes *et al.* (2014), reported that the mature male crabs have increased their claws size and contribute around 20-50% of their body weight. In contrast, this morphological change does not occur in female crabs. Moreover, the male body weight can reach up to 80% more than female crabs at the same carapace width.

The results on the analysis of *S. serrata* growth parameters in Mangkang Wetan showed that male CW$_\infty$ is smaller than female CW$_\infty$. In contrast, the male coefficient value of K was greater than that of the female. The growth of crab males is faster than the females so that the *S. serrata* males reach a faster asymptote. The greater K value in male crabs is due to nutrients utilization (Wijaya *et al.*, 2018). The female crabs use the nutrients for their body growth and reproduction growth including the gonadal development and egg production (Wijaya *et al.*, 2018). This is also strongly influenced by environmental factors such as food availability, temperature, salinity, and also diseases caused by parasites (Viswanathan *et al.*, 2016). All these parameters play an important role in the growth rate.

The growth curve shows (Figure 6.) that in the initial life phase, crabs have rapid growth and then followed by slow growth at a certain age and the crabs do not increase in width anymore. Researchers wrote that the rapid growth of young crabs occurs due to the energy obtained from the food that is mostly used for growth. In adult's crabs, the energy obtained from food is no longer used for its growth, but it is only used to maintenance, defend to the predators and replace their damaged cells (Moksnes *et al.*, 2014).

As seen in Table 4, differences in growth parameters in various locations may due to the differences at the maximum length of samples collected and differences in waters location (Suman *et al.*, 2018). Although growth parameters vary according to regions, environmental factors such as food availability, water temperature, and salinity can affect the growth rate (Sara, 2010).

The study case in Mangkang Wetan Waters showed that the natural mortality rate (M) of male *S. serrata* was greater than the female. This is because males fight more frequently than females, especially when they are approaching their mating time. Fazhan *et al.* (2017) state that male crabs with larger body sizes can secure and protect their female during the entire mating process. Hidayat *et al.* (2017), states that the different natural mortality of mud crabs can be influenced by several things. These include predation, disease, stress, spawning, hunger and old age. Their natural conditions such as natural food sources. Moreover, their competition

can lead to crab death. Furthermore, the different natural mortality rates in every region can be influenced by unstable environmental parameters, as well as the abundance of S. serrata natural foods.

Mortality Analysis and The Rate of Exploitation

The mortality of male crabs captured is higher than female crabs. This postulated that *S. serrata* females tend to caught easier than males. The female crabs naturally migrate to the sea to spawn. Fishermen in Mangkang Wetan waters not only catch in the pond area but also catch on the coast. This coast is the female crabs route to the sea when they need to manage their offsprings and continuing their life in the sea. This is following the statement of Hubatsch *et al.* (2015) that adult male crabs tend to settle in the mangrove forest area while female crabs will hatch their eggs and will move and take some food in deeper marine waters with higher salinity.

Based on the Table 5., *S. serrata* rate of exploitation (E) in Teluk Kendari, Indonesia was the highest, followed by Southern Coastal Region, Bangladesh. While Teluk Lawele, Indonesia was the lowest one. In Mangkang Wetan, the exploitation rate of male crabs was 0.34, while the female was 0.55. This indicated that there has been overfishing or over-exploitation of *S. serrata* females (E> 0.5). While the rate of exploitation of male *S. serrata* is still under the permissible optimal rate of exploitation (E <0.5). Amarasekara *et al.*, (2016), states that the optimum value of exploitation (E$_{OPTIMUM}$) is

Table 4. Growth rate (K) and maximum carapace width (CW∞) *S. serrata* in several waters

Location	CW∞ (mm)	K (year^{-1})	Reference
Teluk Kendari, Indonesia	206	1.01	Suman *et al.* (2018)
Teluk Lawele, Indonesia	211.47	1.38	Sara (2010)
Bangladesh	105.9	0.28	Zafar, *et al.* (2006)

Table 5. Mortality and Exploitation rate of *S. serrata* in several waters

Location	M (year^{-1})	F (year^{-1})	E	Reference
Teluk Kendari, Indonesia	1.03	2.17	0.68	Suman *et al.* (2018)
Teluk Lawele, Indonesia	2.48	1.16	0.31	Sara (2010)
Southern Costal Region Bangladesh	0.49	0.35	0.41	Zafar, *et al.* (2006)

equivalent to E = 0.5. The high rate of exploitation of female *S. serrata* at this study site was due to the relatively high capture rate and a large amount of demand, especially the carrying eggs females.

CONCLUSION

Based on the results it can be concluded that Mud Crab (*S. serrata*) caught in Mangkang Wetan Tugu Waters, Semarang City, Central Java, Indonesia from October to January had a growth rate of 0.93/year (male) and 0.69/year (female). The natural mortality rate were 1.08 / year (male) and 0.89/year (female), mortality due to catch (F) was 0.55/year (male) and 1.09/year (female). The rate of exploitation of males reached 0.34 or 34%, while the rate of exploitation of females was 0.55 or 55%. The rate of exploitation of *S. serrata* females which exceeds 50% indicates that overexploitation has occurred. We suggest that the populations of *S. serrata* are vulnerable in the Mangkang Wetan and the conservation programs in the area are prior.

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