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STUDY ON THE SIZE STRUCTURE AND POPULATION PARAMETERS OF MUD CRAB *SCYLLA SERRATA* IN LAWELE BAY, SOUTHEAST SULAWESI, INDONESIA

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ABSTRACT

Population dynamics of mud crab Scylla serrata were studied in Lawele Bay. The objectives were to determine population size structure and population parameters. Samples were obtained monthly using gillnets and baited traps. Less than 70% of gillnet catches during flood tide consisted of adults. Subadults and juveniles were 28.0% and 4.5%, respectively. Similarly, during ebb tide consisted of 51.7%, 24.2% and 24.1%, respectively. It suggests that gillnets are not size selective gear. In contrast, baited traps only caught adults and subadults with percentage of 90.5% and 9.5%, respectively. The CW∞ and K of males were slightly higher than females namely 21.147 and 1.38 for males and 21.023 and 0.83 for females. The mortality estimates are as follows: natural mortality (M) male = 2.48 and fishing mortality (F) male = 1.2, while M female = 1.78 and F female = 0.75. The difference was due to CW∞, K and Z. The results show that S. serrata population is still under exploited.

Keywords: growth parameters, mortality, population dynamics, S. serrata, size structure

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INTRODUCTION

Mud crabs are important for commercial culture in coastal areas in Southeast Asian countries (Cristensen *et al*., 2004) and constitute large portunid crab which occur in estuaries and mangrove swamps throughout the tropical to warm temperature zone of Indo-Pacific region and Indian Ocean (C-AID Consultants, 2001; Marichamy and Rajapackian, 2001; Chiou and Huang, 2003; Rodrigues *et al*., 2003) including Japan, the Philippines, Indonesia, East and South Africa, the Red Sea (Eldredge and Smith, 2001; Pavasovic, 2004) and Australia (Gopurenko *et al*., 2003; Ward *et al*., 2008). This species become increasingly popular because of their large size and meat quality (Marichamy and Rajapackian, 2001). In Japan, this species is an important local fishery resources and has been selected as one of the target species for stock enhancement program through the production and release of seed (Fushimi and Watanabe, 2000). Throughout their distribution mud crabs are generally found in sheltered waters especially favoring estuaries,

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intertidal swamp, mangrove areas, brackish water ponds and even in the sea (Marichamy and Rajapackian, 2001; Chiou and Huang, 2003). La Sara (2001a) found these species in estuaries occurring both intertidally and subtidally, but majority of adults live subtidally where they burrow in the mud during the day (Fisheries and Aquaculture Department, 2001; NSW Department of Primary Industries, 2008) and emerging at sunset and night to feed (Fisheries and Aquaculture Department, 2001). From such locations mud crabs are found in varying densities and sizes.

Juvenile crabs inhabits intertidal regions associated with mangrove while adult crabs spend most of their lives restricted to sheltered inshore and estuarine area associated with deeper subtidal region (Pillans *et al*. 2005; Ward *et al*., 2008). In Lawele Bay, Indonesia these sizes of mud crab are mainly found adjacent of mangrove areas during flood and ebb tides (Alimuddin, 2000; Latif, 2000), while juvenile generally live in the mangrove zone of inter-tidal areas where they scavenge for plant and animal matter (Ward *et al*., 2008). The adult population density is in contrary with zoeae where the adult population decline with increasing distance from the mouth of an estuary while the highest zoeal abundance are found in the sea waters conditions (La Sara *et al*., 2006). Most commercial activity is focused in the tidal flats adjacent to the coast, and within rivers in some areas. Despite the economic importance of mud crabs which are commonly found in mangroves, creeks, bays, and estuaries throughout Indo-Pacific region, remarkably little are known of their population dynamics (Moser and Macintosh, 2001; Zafar *et al*., 2006).

In Indonesia, these species are widely distributed from west (Sumatera) to east (Papua). It forms an important crab fishery in many coastal areas where there are extensive mangrove swamps and brackish waters. The fishery shows increasing trend of exploitation of mud crab population. In Southeast Sulawesi, the mud crab fishery is year round. Because of demand locally and for export, the price is high hence, leading to intense exploitation. The effect of overexploitation is manifested in the decline of mean size caught and landed. The juveniles are caught for seeding in pond cultures, while adults and subadults are for fattening or for the production of soft shell-crabs, and ovigerous female for premium markets (Le Vay, 2001; Moser *et al*., 2002; Truong, 2008). Currently, many mud crabs fisheries are suffering from the effects of overexploitation (Truong, 2008). Presumably, production and its exploitation are high. For instance, landings of mud crabs *S. serrata* in New South Wales (NSW), Australia from 1999/2000 to 2006/2007 were as the following: 160 tons (1999/2000), 145 tons (2000/2001), 110 ton (2001/2002), 140 ton (2002/2003), 100 tons (2003/2004), 90 tons (2004/2005), 105 tons (2005/2006, and 75 tons (2006/2007) (NSW Department of Primary Industries, 2008).

It is imperative that management strategies must be in place. But unfortunately this is not the case. One of the constraints for management is that catch data is not well monitored and recorded. This is because the buyers do not report the actual production of mud crab to the landing stations and the officers in charge are not able to cover all landing stations because of difficulties in accessibility. In addition, the study on its ecology and biology in natural condition has been neglected.

One of the most powerful methods used in fisheries management is the analysis of catch and effort data over period of time (Sparre and Venema, 1992; Zafar *et al*., 2006; Ward *et al*., 2008), but their status of present exploitation level has yet to be assessed (Zafar *et al*., 2008). Long term records can be

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used to determine trends in the fishery to decide whether the fishery is under or over-fished, whether effort should be reduced and whether the stock is declining or in a stable condition.

Based on the foregoing review of literature and information, there is a dearth of information on the mud crab to be used as basis for its proper management. The objectives of this study were to determine population size structure and population parameters (growth and mortality).

MATERIALS AND METHODS

Sampling mud crab

The study was carried out in Lawele Bay (122°50′ - 123°05′E and 5°05′ - 5°20′S) at the eastern part of main island of Buton, Southeast Sulawesi (**Fig. 1**). Ten sampling stations with different ecological characteristics were chosen broadly categorized as those located in western and eastern sections. Test fishing was undertaken regularly in monthly basis. The gears used were baited traps (bubu) and gillnets.

Ten traps baited with fish were set in each station (**Fig. 1**) in the respective flood and ebb tide in water depth of 100 – 225 cm and 50 – 125 cm, respectively. All these gears were set about 1 h after time lag of either flood or ebb tides. The distance between traps was 20 to 30 m apart and leave them for about 4 h. Similarly, gillnets were set once in the same station, water depth and time.

The catches of mud crabs from each station and month were recorded, identified to species level, sexed and size measured to the nearest 0.1 mm as to its carapace width (CW) and length (CL) using caliper. The mud crabs were also weighed to nearest 1 g using plastic balance.

Aside from test fishing activity, crab production from different locations or areas were monitored.

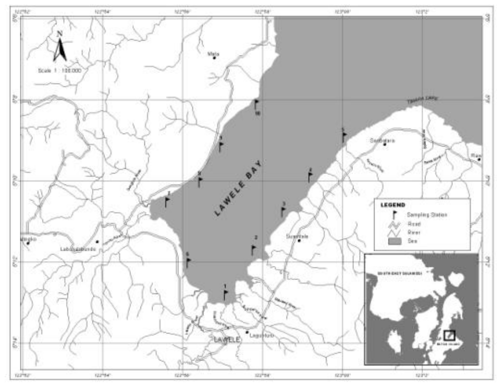

Fig 1. Sampling Station of Mud Crab *S. seratta* in Lawele Bay, Southeast Sulawesi

Data analysis

The catch data from each station was analyzed in terms of size structure, growth parameters (CW, K) and total mortality (Z). Size structure of both sexes was analyzed in terms of CW frequency distribution, while catch and catch per effort was total catch per gear per day operation (trip). It was tabulated per month so that the total catch production by all gears can be predicted. Growth parameters of each sex of mud crab from all stations were analyzed using von Bertalanffy growth function as follows:

$$CW_t = CW_\infty \left\{ 1 - e^{-k(t-to)} \right\}$$

where CW_t is carapace width at t age, CW_∞ is carapace width infinity or asymptotic length, t is age, to is age at t-zero, and k is curvature growth constant.

These parameters were derived from carapace width frequency table generated from gear catches and were computed using ELEFAN I method as incorporated in the FISAT Program (Gayanilo *et al*., 1996).

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The available width-frequency samples were put to estimate Z. This was done by adding up all width-frequency data, then converting them into a catch curve method, Z/K under assumption of a steady state population (Sparre and Venema, 1992; Ingles, 1996; Lavapie-Gonzales *et al*., 1997) using the relationship provided by Pauly (1980):

$$\text{Log}_e\,(N/\Delta t) = a + b \cdot t'$$

where N is the number of mud crabs in a given width class, Δt is the time needed to grow through that width class, 't' is the relative age, 'a' and 'b' are constants.

The equations for computing Δt and t' are the following:

$$\Delta t = \frac{\log_e \left\{ \dfrac{CW_\infty - CW_1}{CW_\infty - CW_2} \right\}}{k}$$

$$t' = \frac{-\log_e \left\{ 1 - \dfrac{CW}{CW_\infty} \right\}}{k}$$

where CW_∞ and K are parameters of VBGF, CW_1 and CW_2 are the lower and upper limits of a given carapace width class, respectively, and CW is the mid-width of the same carapace width class.

The Pauly's equation has the form of a linear regression where the slope b, with sign changed, represents the Z. To convert the width-frequency data into a catch curve, the W_∞ and K values derived from ELEFAN I were used, with $t_0 = 0$. The catch curve was plotted with $\log_e$ (N/Δt) as ordinate and the relative age t' as abscissa. This facilitates the selection of points to be included in the computation of the Z.

Results And Discussion

RESULTS

Size structure

The size frequency distribution of mud crabs caught by gillnets (**Fig. 2 and 3**) and traps (**Fig. 4 and 5**) were classified into three stages, namely juveniles (carapace width of < 70 mm), subadults (carapace width of 70 - < 120 mm) and adults (carapace width of > 120 mm).

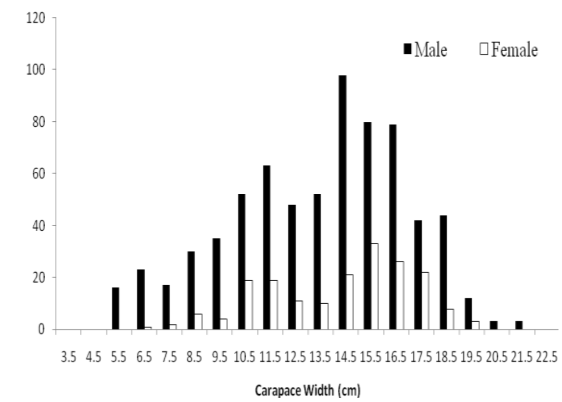

Fig. 2. Carapace width frequency distribution of male and female *S. serrata* caught by gillnet during flood tide in Lawele Bay, Southeast Sulawesi

Data combined from all stations and sexes, about 68.5% of the gillnet catch during flood tide was composed of adult individuals with carapace width of 120 - 200 mm. Less than 1% of adult individuals have carapace width of > 200 mm. Subadults and juveniles represented only 28.0% and 4.5%, respectively (**Fig. 2**). It was almost similar with the gillnet catches during ebb tide. Adult individuals represented 51.7%, while

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subadults and juveniles were 24.2% and 24.1%, respectively (**Fig. 3**).

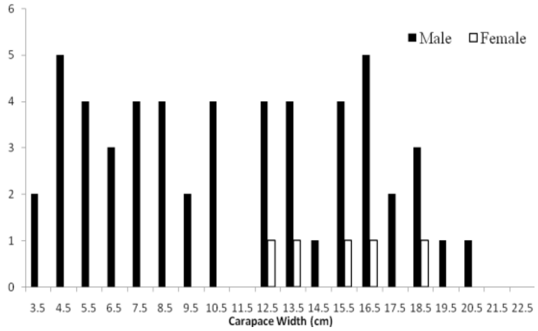

Fig. 3. Carapace width frequency distribution of male and female *S. serrata* caught by gillnet during ebb tide in Lawele Bay, Southeast Sulawesi

In contrast, baited traps did not catch juveniles. The catches were dominated by adults. During flood tide, subadults represented only 9.5%, while adults were 90.5%. Of the 90.5%, the carapace width of > 200 mm was 1.6% (**Fig. 4**). The gears used were caught only eight individuals during ebb tide (**Fig. 5**).

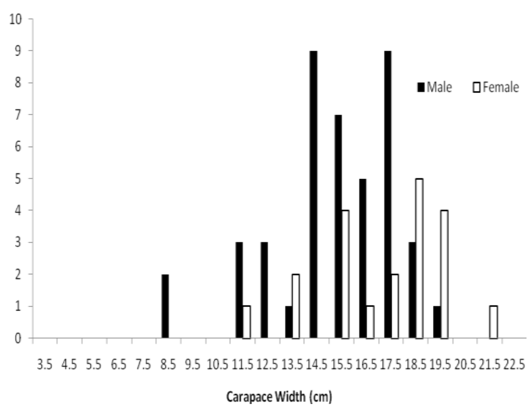

Fig. 4. Carapace width frequency distribution of male and female *S. serrata* caught by baited trap (bubu) during flood tide in Lawele Bay, Southeast Sulawesi

Among size classes distribution of both sexes, the highest proportion of catch (> 10%) during flood tide were sizes between 140 mm and 170 mm for gillnet catches and between 140 mm and 190 mm for baited traps, respectively. It differed with gillnet catches during ebb tide where only size of 160 – 170 mm has high proportion. Baited traps proportion catches were all higher than 10%.

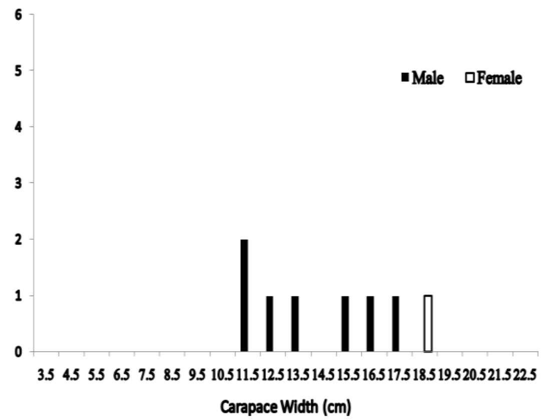

Fig. 5. Carapace width frequency distribution of male and female *S. serrata* caught by baited trap (bubu) during ebb tide in Lawele Bay, Southeast Sulawesi

Catch and catch per effort

Since there were no landing stations around the study area, the total catch of *S. serrata* was difficult to estimate. A census of the number of fishermen from each site of Lawele Bay was undertaken. This proved difficult as fishing is a part time job to farming. There were a total of 32 fishermen were included in the computation because they caught only crabs using gillnets and traps inside the study area.

The fishermen were interviewed during landings giving information on catch. The results show that gillnets produced a higher total catch than baited traps. It was because of the inclusion of the smaller sizes of juveniles,

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which would be marketed with low price or confined in a bamboo cage for fattening.

The abundance of *S. serrata* was higher from June to September. The mean catch of gillnet during this period was 2.9 – 6.01 kg day^{-1}man^{-1}, and it corresponded to total catch of 588.7 – 1177.96 kg month^{-1} (number of fishing days was 7 days month^{-1}). The same trend is shown by the catches of baited traps ranging from 1.35 to 2.84 kg day^{-1} man^{-1}. Although the catch of baited traps was few in term of individuals, but the body weight and size of each individual was large. It was because the gears were designed for large sized crabs. The sizes of *S. serrata* from November to April were still small and mostly juveniles.

Growth parameters

The monthly carapace width frequency distribution in the respective sex of male and female was analyzed using ELEFAN I. The data of each sex was combined from all stations during flood and ebb tides from July 1999 to July 2000. The results of the best fitting growth curve used plot restructured frequency of ELEFAN I analysis.

The estimate of growth parameter ($CW\infty$) as an input to the ELEFAN I analysis was derived using the Powell-Wetherall's Plot. The K values (**Table 1.**) were obtained from scan of K values that has the highest Rn using ELEFAN I. **Table 1.** shows that $CW\infty$ of males was higher than females, as shown its curvature parameter of VBGF (K).

Table 1. Growth parameters of *S. serrata* in Lawele Bay, Southeast Sulawesi

Parameter	Males	Females
$CW_{\infty\ (cm)}$	21.147	21.023
$K_{(/year)}$	1.38	0.83

Total mortality

The estimates of Z were computed using the length-converted curve under the assumption of a steady state population. The estimation of Z for males was higher than of females (T**able 2**). It was similarly with the estimates of M using the Pauly's empirical equation (the mean temperature is 29.29ºC). It suggests that M of *S. serrata* is more than half (67.39%) among males and about two-thirds (70.36%) for females based on Z estimates.

DISCUSSION

Size structure

Generally, the sizes of mud crabs caught were dictated by buyers. There were three classes of mud crab sizes traded in Indonesia which was related to the prices of each class. The first class was > 800 g body weight (corresponding with 131.65 – 212.45 mm) with price of Rp.25,000 – Rp.30,000 per kg (\$ 2.5 - 3.0). The second class was 500 - < 800 g with price of Rp.18,000 – Rp.20,000 (\$ 1.8 - \$ 2.0) and the third class was < 500 g with price of Rp.8,000 – Rp.10,000 (\$ 0.8 -

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$ 1.0). This classification affected gillnet and baited trap mesh sizes used. Majority of crabbers preferred the first class as shown at the size frequency distribution. It was caught from June to August (La Sara, 2001b).

As shown in (**Figs 2 - 3)**, CW frequency distribution based on catch by gillnets implied the exploitation of *S. serrata* ranging from 30 mm to 220 mm. It further implied that gillnet was a non-selective gear. Baited traps designed for large sizes only caught subadult and adult sizes (**Figs 4 - 5**) ranging from 80 mm to 220 mm. For management purposes the use of baited traps, which supported awareness on resources sustainability, is advisable.

Similar activity also happens in several places such as in Tanzania today which fishermen catch mud crabs of small adult (>300 g; > 120 mm CW) from the wild (Moksnes, 2002). In Australia, mud crab live for up to four years and the fishery targets mud crab in the one to three year age groups (Department of Primary Industry and Fisheries, 2001). It was further explained that a single species fishery in which baited traps (pots) are normally used to take live mud crabs. Mud crab *S. serrata* accounts for more than 99% of the catch (Department of Primary Industry and Fisheries, 2001). A major management outcome arising directly when the minimum size limit of female was raised from 130 mm CW to 140 mm. This precautionary strategy means that more 70% of female are protected from direct fishing mortality until they reach maturity.

In the present study, the largest size caught was a female with 212.45 mm carapace width (1,550 g body weight) and a male with 210.00 mm carapace width (1,700 g body weight). However, there was one male with carapace width of 199.05 mm and body weight of 2,110 g. The latter size of body weight and the first one constituted the biggest *S. serrata* I have found in Southeast Sulawesi. Both individuals were caught in August and September 1999, respectively.

Since population of *S. serrata* in Lawele Bay spread throughout the year, where major peak was in July and minor peak in February, it coincided with high relative abundance of subadult and adult sizes for major peak and juvenile size for minor peak. High frequency of large sizes (**Figs 2 - 5**) implied clearly that this species tends to occupy estuarine areas in which they prefer shallow water with low salinity.

The lower percentage frequency of each size class of females throughout the year compared with males in the same size class could be partly explained as follows: (1) possibly females occupied specific ecological niches such as intertidal burrows; and (2) adult females migrated from estuarine to seawater before spawning (Department of Primary Industry and Fisheries, 2001; Bishop Museum and University of Hawaii, 2002; Ward *et al*., 2008). Those feed at much lower levels and would not be attracted, therefore, to baited trap (Jebreen *et al*., 2008). It had been observed in the earthen pond that ovigerous females *S. serrata* just kept quite along the day in the bottom and very rare swim freely (La Sara, 2001b). The absence of *S. serrata* from spawning grounds indicated that they might either be subject to massive natural mortality including that from predation, or they might migrate to seaward (Department of Primary Industry and Fisheries, 2001; Ward *et al*., 2008).

Catch and catch per effort

Accurate and consistent catch (CPUE) data are vital to population dynamic studies. Although *S. serrata* is a commercial species among crustaceans, there is no attempt was done to gather information on crab landing in

Indonesia. The data of catch and effort in the present study was initiated through monthly interview with fishermen who were using gillnets and baited traps.

The gillnet mean catch was slightly higher than the baited traps. The gillnet used with mesh size of 2 cm can catch a wide range of carapace width sizes considering as non-selective gear. The small sizes (juveniles) were frequently caught, particularly from January to February. Of 32 fishermen (crabber) the mean catch ranged from 0.78 to 6.01 kg day^{-1} man^{-1} (2.72 ± 1.52 kg day^{-1} man^{-1}). The estimates of monthly total catch ranged from 120.12 to 1177.96 kg (488.51 ± 343.41 kg). The lowest total catch was in December, while the highest was in July. These corresponded to the number of crabs caught monthly. Although the number of individuals was high from January to February but the sizes were still small (juveniles). Hence the weight of individual was low.

The baited traps were specifically designed for large crabs with dimension of 100 cm x 60 cm x 30 cm and mesh size of 3.5 cm have the mean catch of 0.3 – 2.84 kg day^{-1} man^{-1} (1.38 ± 0.58 kg day^{-1} man^{-1}). This gear was very selective. It was occasionally found that juveniles could enter inside and escape easily. The estimated monthly catches ranged from 10.5 – 168.63 kg (93.52 ± 57.88 kg). When the crab sizes were still small (from November to March), majority of fishermen shifted to catch other species. Pelagic fish such as tuna, mackerel and shark were commonly fished. This traditional awareness of some fishermen should be disseminated to other fishermen as far as sustainability of resources concerned. It was supported with the number of days for fishing which was only 14 – 17 days $month^{-1}$ (average 7 days $month^{-1}$). This fishing activity was based on lunar phase which related with feeding activity of *S. serrata*. In several coastal areas of Southeast Sulawesi, fishermen usually caught mud crab 3 days after new moon up to 3 – 4 days before full moon. But there were also evidence that fishermen sometime caught mud crab and shrimp (*Penaeus monodon* and *P. merguiensis*) using baited trap or gill net when the moon was dark (3 – 4 days after full moon). Febriany (2009) found that *P. merguiensis* in Morowali, Central Sulawesi was also more abundance during dark moon than full moon. According to Moser and Macintosh (2001) that nocturnal peak activity of *Uca* is hypothesized to help reduce predation. The authors further noted that recruitment of Ocypodae, *Metaplax* and other grapsids in Klong Ngao is concentrated around full moon and new moon and is cross-correlated with tidal amplitude.

Growth parameters

The nature of crustacean growth by molting has led to much difficulty in determining the true growth rate under natural conditions (Zafar *et al*., 2006). Most of the studies on the growth has been made on crustaceans kept in tanks or cage/pen culture system (Millamena and Bangcata, 2001; Mwaluma, 2002; Trino and Rodriguez, 2001; 2002; Mirera and Mtile, 2009) and by tagging (Moser *et al.*, 2002; Ward *et al*., 2008). Zafar *et al.*, (2006) reported that growth of mud crab *S. serrata* was successfully cultivated in the earthen ponds and cages of Bangladesh coastal areas based on natural source of seed, while Moksnes (2002) reported growth of mud crab kept in pen culture. Moser *et al* (2002) estimated growth of mud crab *S. olivacea* based on tagging and recapture study using a size-transition matrix which accommodates the discrete and stochastic nature of mud crab growth by assigning crabs to size classes and giving the probability values for moving from one size class to another. No data available for growth of *S. serrata* under natural condition in tropic region.

In the present study, growth parameters (**Table 1.**) were derived from carapace width frequency table using ELEFAN I method (Gayanilo *et al*, 1996). The same method has been used by Zafar *et al* (2006) in determining population parameters and stock assessment of *S. serrata* in Bangladesh.

As shown in **Table 1,** males grow faster than females. However, the study conducted by Mirera and Mtile (2009) showed that males were observer to have similar growth with females. This study was opposed to the study of Mwaluma (2002) were female crabs grew faster than male. The difference in the K between sexes could possibly explain the discrepancy in the sex ratio (Ingles, 1996). A relatively high K value and slightly low of length asymptotic is typical to most the tropical species (Pauly, 1984). The K values in the present study were different with the work of Zafar *et al* (2006) who conducted a research in Chakaria Sundarban and its adjacent areas of Moheskhi and Kutubdia channel, Bangladesh. Zafar *et al.,* (2006) measured only carapace length (CL), while in the present study measured carapace width (CW). The different of both CW asymptotic (211.47 mm for male and 210.23 mm for female) of the present study and CL asymptotic of Zafar *et al* (2006) (105.9 mm for male and 105.0 mm for female) were significantly different. Apparently the growth parameters of *S. serrata* in Lawele Bay are quite similar with other Portunidae (**Table 3**). These data led to conclude that there were regional differences among species in catabolic K but not in the $L\infty$.

Despite growth parameters vary according to areas, environmental factors such as availability of food, water temperature and salinity may affect the growth rate. For instance, mud crab can tolerate wide variations in temperature of 12 - 35°C (eurythermal) and salinity of 2 – 50 ppt (euryhaline) (Masterson, 2007; NSW Department of Primary Industries, 2008). The study of Meynecke (2009) showed that correlation of catches of *S. serrata* with rainfall suggest that rainfall and temperature threshold exist and if exceeded can cause loss or production. Other study showed that water temperature was shown to influence intensity of mud crab behavior (Truong, 2008). It has been found that their activity and feeding slow greatly below 20°C (NSW Department of Primary Industries, 2008). Ruscoe *et al* (2004) showed that the highest survival and growth rate of juvenile mud crabs was achieved at 30°C, while Mwaluma (2002) indicated that successful pen culture of the species could be carried out in waters that ranged seasonal between 25°C and 36°C. Truong (2008) concluded that temperature in the range of 28.5°C to 30.5°C is most suited for this species.

In food availability, blue crabs female were more attracted to the poultry bait than were male crabs (Middleton *et al.,* 2000). Similar result showed that female shore crabs (*Carcinus maenas*) exhibit stronger feeding responses than males across the year with a significantly reduced feeding response in males during the summer reproductive season (Hayden *et al*., 2007).

Total mortality

Many factors in the marine environment act to reduce the chances of survival of individuals in a population. These include adverse conditions, lack of food, competition and predation (King, 1995). Therefore, knowledge of the total mortality rate, and its components of fishing and natural mortality, is essential for an adequate understanding of

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the population dynamics of an exploited population. Haddon *et al.*, (2005) noted that fishing mortality difficult to estimate precisely at high values. Similar difficulties are associated with estimating high rates of total mortality. *S. serrata*, despite its economic significance, its dynamic population remains poorly understood as there is no information on mortality and stock assessment have been done in tropical regions. Considering this fact, care must be taken in the estimates of the total mortality.

Table 2. Total mortality (Z) and natural mortality (M) of *S. serrata* in Lawele Bay, Southeast Sulawesi

Parameter	Males	Females
Z	3.68	2.53
M	2.48	1.78

The Z estimates of male *S. serrata* was higher than female. Of about 67.39% was contributed from M for males and 70.36% for females (**Table 2**). The higher M of females was apparent, particularly after mating and during their migration to seawater to spawn, while higher F for males was mostly due to the occupied intertidal flat or shallow water with high fishing activities.

Table 3. Parameters for von Bertalanffy growth equation for Portunidae at different locations around Asian and Australian waters

Location	Species	Sex	K/year	$L_{\infty\ (cm)}$	Reference
Bantayan, Philippines	*P. pelagicus*	Male	0.98	22.5	Ingles (1996)
		Female	0.70	22.5	
Mangalore, Malpe and	*P. sanguinolentus*	Male	0.99	19.5	Sukamaran and
Karwar, India		Female	0.82	18.8	Neelakantan
(1997)					
	P. pelagicus	Male	1.14	21.1	Sukamaran and
		Female	0.97	20.4	Neelakantan
(1997)					
Chakaria Sundarban,	*S. serrata*	Male	0.28	10.59	Zafar *et al* (2006)
India		Female	0.36	10.5	
Northern Territory,	*S. serrata*	Male	1.46	15.25	Ward *et al* (2008)
Australia		Female	0.81	18.54	
Lawele Bay, Indonesia	*S. serrata*	Male	1.38	21.1	Present Study
		Female	0.83	21.0	

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Similarly, studies on *Portunus* showed that Z as well as M of males was higher than females (**Table 4**). Ingles (1996) analyzed M of *P. pelagicus* of Bantayan, Philippines was lower than F. Sukumaran and Neelakantan (1996) presented data of average M of *P. sanguinolentus* (M = 1.08 for males; M = 0.96 for females) and *P. pelagicus* (M = 1.15 for males; M = 1.04 for females) in Indian waters and found lower than F. Similar result also was found on M of male and female F.

Table 4. The values of Z, M and F of Portunidae at different locations around Asian and Australian waters

Location	Species	Sex	Z	M	F	Reference
Bantayan, Philippines	*P. pelagicus*	Male	5.51	2.36	3.15	Ingles (1996)
		Female	2.75	1.37	1.38	
Mangalore, India	*P. sanguinolentus*	Male	3.49	na	na	Sukumaran and
		Female	2.64	na	na	Neelakantan (1996)
	P. pelagicus	Male	6.85	na	na	Sukumaran and
		Female	5.31	na	na	Neelakantan (1996)
Karwar, India	*P. sanguinolentus*	Male	5.22	na	na	Sukumaran and
		Female	3.84	na	na	Neelakantan (1996)
Karwar, India	*P.pelagicus*	Male	4.29	na	na	Sukumaran and
		Female	3.55	na	na	Neelakantan (1996)
Chakaria Sundarban,	*S. serrata*	Male	0.84	0.49	0.35	Zafar *et al* (2006)
India		Female	0.96	0.58	0.38	
Northern Territory,	*S. serrata*	Male	6.6-12.2	na	na	Ward *et al* (2008)
		Female	3.2-4.6	na	na	
Lawele Bay,	*S. serrata*	Male	3.68	2.53	1.15	Present study
Indonesia		Female	2.48	1.78	0.70	

-na = not available

The lower F than M in Lawele Bay may be true, since fishing activities were low compared with fishing activities on *Portunus* in Bantayan waters, Philippines (Ingles, 1996) and Indian waters (Sukumaran and Neelakantan, 1996). In most crab species, the male grows to a large maximum size than does the female (**Tabel 1**), and thus is more vulnerable to the fishery, although there were males similar growth with females (Mirera and Mtile, 2009). Specifically, it may be stated that the difference in the Z between sexes may be attributed to the higher K among males. However, the study on other crustaceans such as *Panulirus* showed that Z was apparently different among locations. All these authors agree that the primary cause of Z came from F, while the cause of M was unknown although it contributed significantly to the Z. Moreover, King (1995) suggested that the M resulted very largely from predation.

In *S. serrata* in Lawele Bay and other places, natural enemies were apparent such as barnacles, monitor lizards and wild pigs. Other enemies and prey on *S. serrata* found in Lawele Bay were herons, sharks, water mongooses and crocodile. Possibly sharks may prey on *S. serrata* only females during movement seaward to spawn. Mirera and

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Mtile (2009) noted that mortality observed throughout experimental period was failure to molt, dying during molting process or shortly afterwards and predation with other crabs after molt due to soft shell.

Ingles (1996) predicted large mortalities on *P. pelagicus* are associated with either the planktonic phase or during ecdysis. An additional observation in the present study showed that the condition of *S. serrata* during molting, usually nighttime, was very vulnerable to predation because the animal released scent or a perceptible smell which may attract its co-species to be preyed. This animal was very ferocious as shown by its behavior for about 48 hours after ecdysis by eating its old carapace.

CONCLUSION

The vulnerable period of *S. serrata* was during molting in which they were very weak and soft-shelled. The source of mortality of mud crabs may be caused by predation from their co-species, other natural enemies and from fishing. Females were the most vulnerable after mating and during spawning as shown by high M of about 70.36% from Z, while males were more vulnerable to the fishery (F) because they grew faster than females and occupied intertidal area which has high fishing activities. The estimate M for males was lower than females which was 67.39% from Z.

High mortality of both sexes led to cause the recruitment of mud crab which in turn might affect the number, size distribution and sex ratios. The existing effort activities of both sexes *S. serrata* should be maintained and possibly reduced to allow recruitment maximum. Because M contributed more than F then effort and concern should be directed to the habitat management.

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