The reproductive biology of blue swimming crab *Portunus pelagicus* in Southeast Sulawesi waters, Indonesia

[1]La Sara, [1]Wellem H. Muskita, [1]Oce Astuti, [2]Safilu

[1] Faculty of Fisheries and Marine Sciences, Halu Oleo University, Bumi Tridharma, Kendari 93232, Southeast Sulawesi, Indonesia; [2] Department of Biology, Faculty of Education, Halu Oleo University, Bumi Tridharma, Kendari 93232, Southeast Sulawesi, Indonesia. Corresponding author: L. Sara, lasara_unhalu@yahoo.com

Abstract. Blue swimming crabs (BSC) (*Portunus pelagicus*) fisheries in Southeast Sulawesi waters have experiencing huge pressure, however studies on their reproductive biology were limited. The objective of the study was to find out the growth model, size at the first maturity, fecundity, and sex ratio disparity of BSC. The samples were collected monthly during June 2014 - April 2015 using gillnets, crab pots or hand-picking. Berried females were collected for fecundity (F) analysis. Relationship between weight (W) and carapace width (CW) were analyzed using a simple linear regression. The CW size of the first maturity was pointed out at 50% of frequency cumulative (CW_{50}), while relationship between F and CW was analyzed following $F = a*CW^b$. Sex ratio of both sexes was tested using the Chi-square (α = 0.05). The result shows growth model of both sexes was "allometric" (b < 3) following equation of W = -1.6181 + 0.0224*CW for males and W = -1.7909 + 0.0238*CW for female. The relationship between F and CW was $F = 80.443e^{0.0236\ CW}$ (r = 0.7679). This organism produces high fecundity as its biology reproductive strategy to maintain its population. Males and females attaine the first maturity at CW_{50} of 11.957 cm and 10.802 cm, respectively. The sex ratio generally females preponderate over males, however, the Chi-square test was not significantly different. Factors affecting sex ratio disparity were mainly locations (water quality), migration and distribution patterns according to sex, sampling method, gears catchability, mortality and growth, reproduction activities, and CW sizes.

Key Words: growth patterns, fecundity, first maturity, *Portunus pelagicus*, sex ratio.

Introduction. Blue swimming crabs (BSCs) (*Portunus pelagicus*), aside shrimps, mud crabs, and lobsters, are consumed by many people due to its high protein. BSCs live in a wide range of inshore and continental shelf areas, including sandy, muddy or algal and seagrass habitats, from the intertidal zone up to at least 50 m water depth (Edgar 1990; La Sara & Astuti 2015; La Sara et al 2016a). In Southeast Sulawesi waters, they are found in habitat having substrate of sandy dominant – mix with mud in intertidal zones which is over-grown by seagrass and mangrove. Habitats of BSCs are easy to be reached by fishermen making its fishing intensive all year round (La Sara & Astuti 2015; La Sara et al 2016a; Permatahati 2016).

BSCs population in Southeast Sulawesi waters have been heavy exploited using gillnets, collapsible crab pots and some handpicking since decades (La Sara et al 2014; La Sara & Astuti 2015; La Sara et al 2016a; Muchtar 2016; Basri 2016). Unfortunately the data of its exploitation and habitat are not recorded well so it is difficult to assess its population stock. BSCs exploitation are very intensive because all mini plants of crab meats processing support fishermen with gillnets or crab pots to catch BSCs. Those mini plants collect all BSCs caught (La Sara et al 2010; La Sara et al 2014; La Sara et al 2016a). The negative impact of exploitation on BSCs population around Southeast Sulawesi waters have risen apprehensive because of: (1) its carapace width (CW) size is dominated by small size of < 7 cm, (2) the individual number caught and biomass per trip is few, (3) its fishing ground is continuously narrow, limited and moving afield from shore line (La Sara & Astuti 2011; La Sara et al 2014; La Sara et al 2016a; La Sara et al

2016b), and spawning potential ration ±14% (La Sara et al 2014; La Sara & Astuti 2015; La Sara et al 2016b). They point out that those problems of BSC fishery are increasingly complex due to data of reproductive biology and ecology are not recorded well (La Sara & Astuti 2015; La Sara et al 2016c). Other factors affecting BSCs population are their habitat of seagrass and surrounding mangrove forest have been experiencing destructive (La Sara et al 2014; Permatahati 2016). Deterioration of water quality due to pollution from mining activities also gives contribution on BSC population decreased. Therefore, its harvest control is difficult to be implemented due to unavailable of management formulation (La Sara et al 2014; La Sara & Astuti 2015; La Sara et al 2016b).

The studies on BSCs up to the present in Southeast Sulawesi waters are very limited. Several studies on BSCs had been taken regarding variation of fishing capture (Sanitha 2007), size composition (Syarif 2007), habitat and abundance (Wangsaatmaja 2007), establishing marine protected area (La Sara et al 2015), ecology and population parameters (La Sara et al 2010), and population dynamics (La Sara 2010), while the recent studies on reproductive biology are conducted (La Sara et al 2016b; Permatahati 2016) but those studies were not directed to its management based on biological aspects. The data found in the present study has an important role and strategic for formulating its management to attain its population sustainability. The objectives of the study were to find out the growth model of blue crab, size at the first maturity of both sexes, fecundity, and sex ratio disparity.

Material and Method. The study was conducted from June 2014 to April 2015 in the very intensive exploitation of BSC in Tiworo Strait of Southeast Sulawesi (Figure 1).

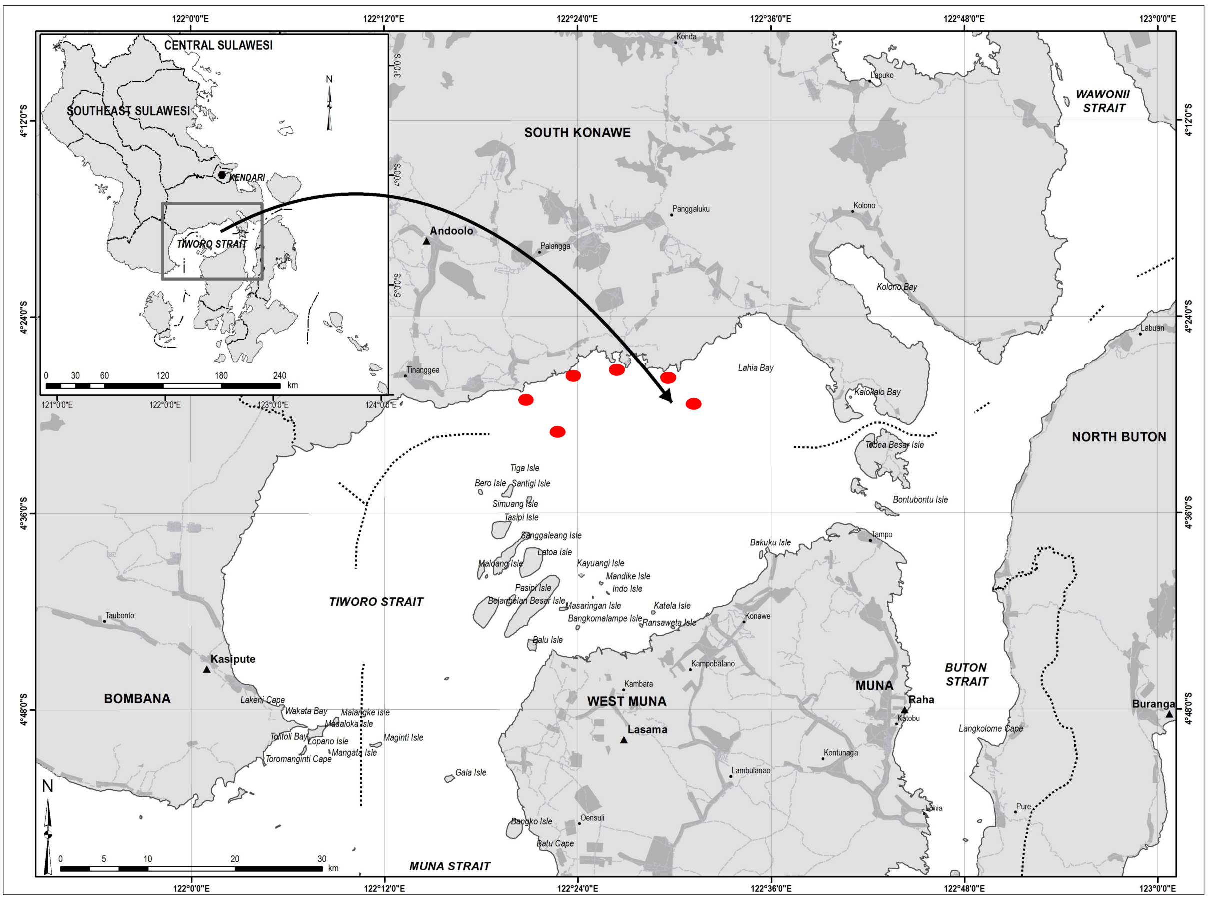

Figure 1. Map of sampling BSC in Tiworo Strait of Southeast Sulawesi waters, Indonesia (red circles is sampling location).

Parameters of reproductive biology were measured consisting of CW, body weight (W), fecundity (F), and sex. Water temperature and salinity were also measured at the same time of sampling BSCs at each sampling location. Monthly BSC samples were undertaken randomly because fishing ground of BSCs distribute evenly. The gears used were gillnets (lenght = 1200 m; height = 1 m) with mesh size of 4.5 inch and traps (lenght = 54 cm; width = 36 cm; height = 19 cm) or handpicking. All BSCs caught were recorded, identified its sex and measured its CW using a caliper to the nearest 0.1 mm and weighed its body weight to nearest 1 g using electronic balance (CAMRY EK 5055 Max 5 kg) (La Sara 2001a, 2010; La Sara et al 2014). Sex identification was based on its morphological characteristics at abdomen part. The female samples beared eggs were also collected. Their eggs were all taken out from the abdomen and then preserved in 5% buffered formalin solution in seawater. It was weighed to nearest 0.01 g using electronic balance. For determination of F, sub-samples were taken and weighed (La Sara et al 2002). These sub-samples were counted under binocular microscope (Nikon FDX – 35; Nikon H – III; Nikon Eclipse E 400). The F is computed using raising factor (La Sara et al 2002) as follows:

$$F = n\left(\frac{W}{\bar{w}}\right)$$

where F is fecundity, n is the number of egg samples, W is total weight of eggs and $\bar{w}$ is mean weight of eggs.

The number of eggs produced (fecundity) was plotted against CW using $F = a*CW^b$; where F is fecundity; CW is carapace width, and a and b are constants.

The relationship of W to CW of males and females was determined using the regression analysis. Male and female can be classified into immature or mature based on the morphology of the abdominal segment (Tongdee 2001). Using this classification criterion, the percentage of mature was calculated for each 1 mm size interval (Balasubramanian & Suseelan 1998; Tongdee 2001). Percentage of mature was plotted against CW. The size at 50% maturity was chosen as an appropriate measure of the size at maturity (Somerton & MacIntosh 1983; Knuckey 1996; Balasubramanian & Suseelan 1998; Tongdee 2001).

Sex ratio of BSCs is the number of individual male and female sexes. The expected and observed ratios of male to female were tested using the Chi-square test at α = 0.05 (Sudjana 1989).

Results

Growth of BSC. The growth patterns of BSCs were known from a simple regression analysis between W and CW. It was found that correlation coefficient (r) of W and CW of both sexes were significance and positive, while regression coefficient (b) of both sexes were relative the same (b < 3) (Figure 2).

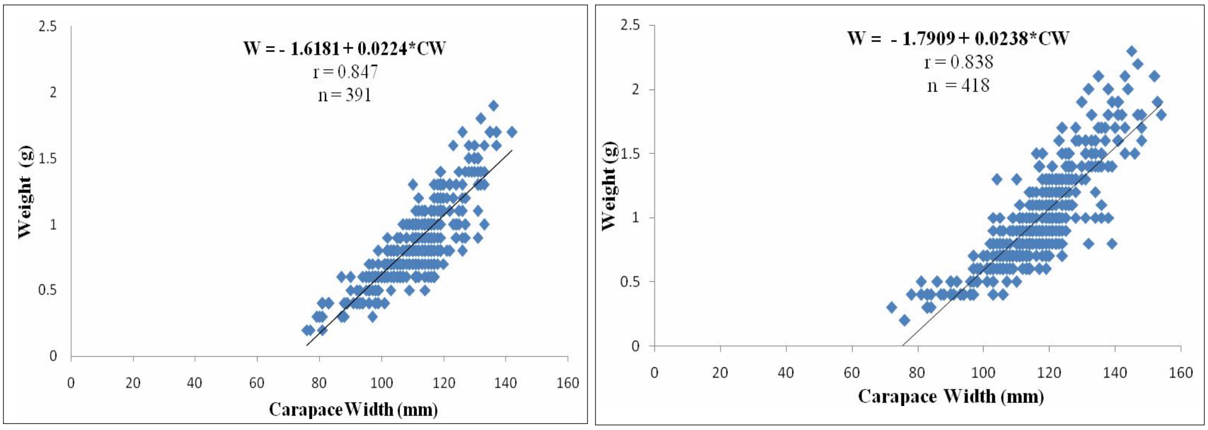

Figure 2. The relationship between body weight (W) and carapace width (CW) of male (left) and female (right) BSCs in Southeast Sulawesi, Indonesia.

The relationship of fecundity and BSC carapace width. The eggs number produced female BSC (n = 40) with CW sizes of 10.6-15.2 cm increased exponentially following increasing CW sizes. The F of BSCs were 763,413-2,868,284. The relationship of F and CW followed the equation of $F = 80.443e^{0.0236\ CW}$ (r = 0.7679) (Figure 3).

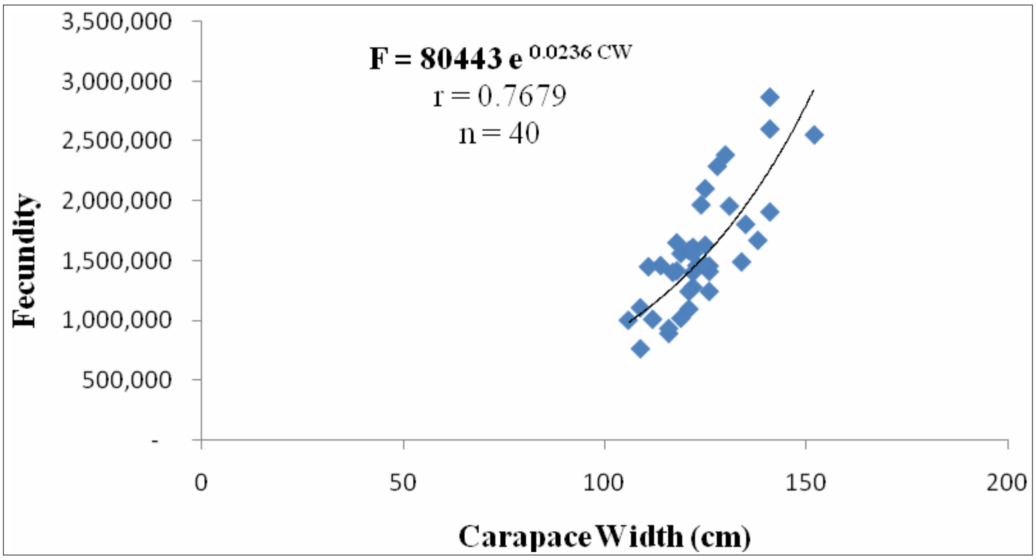

Figure 3. The relationship between fecundity (F) and carapace width (CW) of BSCs in Southeast Sulawesi, Indonesia.

The first maturity of BSC. Determination of size at maturity for males and females is an important factor in fisheries management. The CW sizes of both sexes of BSCs caught were ranging 7.6-15.8 cm and 7.2-15.9 cm, respectively and leading to find out an inflection point of 50% (CW_{50}) frequency cumulative at 11.957 cm and 10.802 cm, respectively. Those values were reflection of sizes for the first maturity of both sexes, respectively (Figure 4).

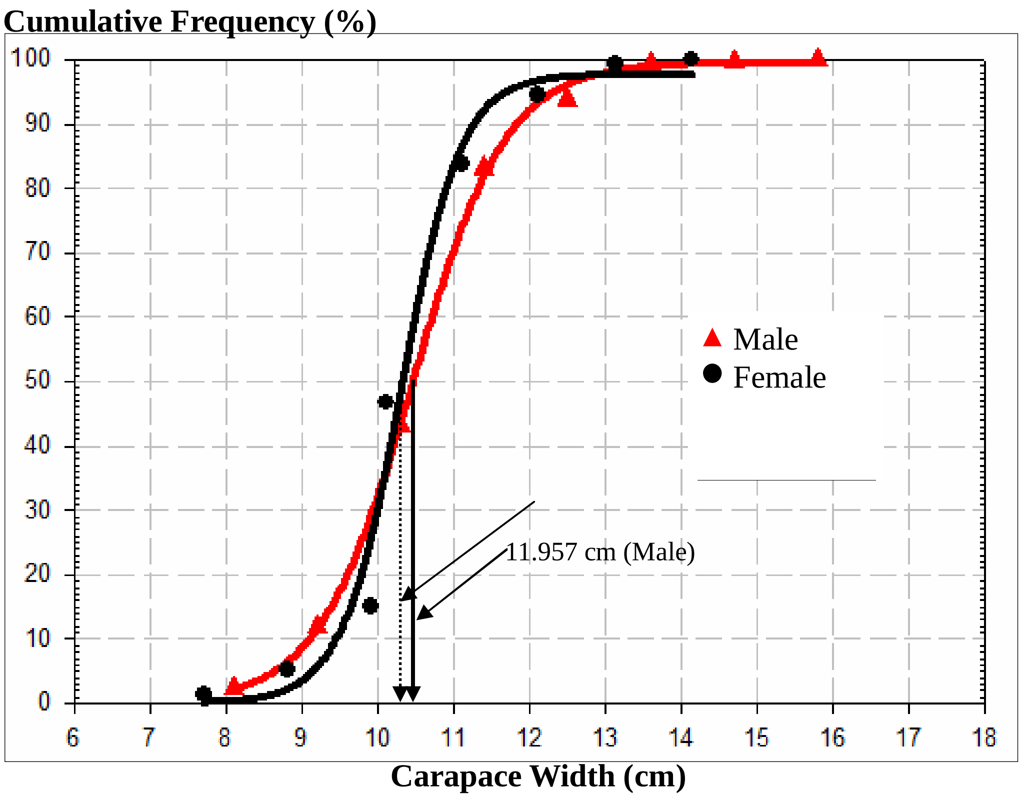

Figure 4. The BSC CW sizes at first maturity of male and female in Southeast Sulawesi waters, Indonesia.

Sex ratio of BSC. BSC samples showed that generally sex ratio of female preponderated over male (male: female = 1: 1.032). However based on the Chi-square test that BSC sex ratio in the present study was not significantly different ($p > 0.05$).

Discussion

Growth of BSC. The growth of BSCs or other crustacean are not continuous, and size increases occur only immediately after experienced molting. The growth is therefore a function of the molt increment and the frequency of molting (Hancock & Edwards 1967). Molt in crustacea includes all physiological and morphological changes involved in preparation for and recovery from ecdysis (Aiken 1980; Phillips et al 1980). Old carapace which small sized is replaced with the new one after somatic mass increased in the BSC body. Along this process of somatic mass increased is followed by forming an elastic thin layer just beneath old carapace. After old carapace was ecdysised immediately this thin layer and soft-shelled replaces it and in the few minutes it becomes harder (La Sara 2001a). Kangas (2000) explained that hardening process happens because BSCs reabsorbs calcium from an old carapace and places it in its blood and/or organ. The BSC also absorbs calcium from sea water and used it for recalcification of new carapace (Kangas 2000; La Sara 2001a). Generally BSC experiences molting several times during its life circle. Their CW increased in sizes and followed by their body weight. These can be regressed to know growth pattern. In the present study (Figures 2 and 3) growth patterns (b) follows allometric growth ($b < 3$). Similar results were found in the previous study in Lasongko Bay of Southeast Sulawesi waters for both sexes namely $b < 3$ and $r = 0.8688$ for male and $r = 0.8624$ for female (La Sara et al 2010). Sanitha (2007) also found relative similar regression coefficient (b) but regression coefficient (r) was relative lower for both sexes namely male of 0.572 and female of 0.767. The difference of regression coefficient was shown by BSC in Western Australia waters and Trang coastal waters of Thailand which regression coefficient of male and female were > 3.00. Several previous studies on the same species were found variation of regression and correlation coefficient (Table 1). The difference of growth coefficient and correlation coefficient on crustacean could be caused by several factors such as age, genetic derivation, and seasons leading to affect water temperature. Sex, level of mature, and disappearance organs could contribute to those both coefficients.

Table 1

Regression (b) and correlation (r) coefficients of body weight (W) and carapace width (CW) relationship of BSCs found in several regions

No	*Location*	*Sex*	*B*	*r*	*N*	*Sources*
1	Purirano, Kendari	Male	3.4924	0.9484	60	Sutriani (2002)
		Female	3.5435	0.9557	57	
2	Purirano, Kendari	Male	2.5925	0.9094	44	Risnawaty (2003)
		Female	1.9710	0.7817	32	
3	Toronipa, Kendari	Male	2.7031	0.9540	179	Basri (2016)
		Female	2.9647	0.9482	191	
4	Lasongko Bay	Male	0.572	-	-	Sanitha (2007)
		Female	0.767	-	-	
5	Western Australia	Male	3.260	-	-	Kangas (2000)
		Female	3.056	-	-	
6	Trang coastal waters, Thailand	Male	3.219	0.88	-	Sawusdee & Songrak (2009)
		Female	3.186	0.87	-	
7	Bandar Abbas, Persian Gulf, Iran	Male	2.7570	0.93	-	Kamrani et al (2010)
		Female	2.7480	0.88	-	
8	Lasongko Bay of Southeast Sulawesi waters	Male	0.2575	0.8688	741	La Sara et al (2010)
		Female	0.2758	0. 8624	883	
9	Tiworo Strait of Southeast Sulawesi waters	Male	0.0224	0.847	391	Present study
		Female	0.0238	0.838	418	

Water temperature significantly affects feeding activities and growth rate of crustacea

(Kangas 2000; Sunarto 2012). Average water temperature and salinity measured in the present study were 30-33°C and 26-32 ppt, respectively. Such water temperatures and salinities are suitable and support feeding activities and growth rate of BSCs. BSCs in Dawesville Channel, Australia were found in water temperature of 24-25°C (de Lestang et al 2003a). A few females with eggs can be found throughout the year if temperatures were in the range 15-25°C, while adult BSCs in South Australia were found in salinity between 30 and 40 ppt (Potter et al 1987). Water temperature may affect each of life stage of BSCs which in turn affect both coefficients. Kangas (2000) explained that mature BSCs only moult once in a year. During winter period growth rate of BSCs was slow because of water temperature decrease. In the water temperature of 24°C juvenile blue crabs (CW of 30-40 mm) may experience molting every three weeks and grew to 7-10 mm every moult (Meagher 1971). He explained further that time needed between molt in the water temperature of 20°C was around 4 weeks. In South-west coast of India, BSC with CW of 32.5 mm grew to be 70-80 mm in period of 7 months (Sukumaran & Neelakantan 1997), while in the laboratory condition the juvenile BSCs with CW of 15 mm reaching 23 mm in the period of 3 weeks (Prasad & Tampi 1953).

The relationship of fecundity and BSC carapace width. The knowledge about fecundity constitutes an important part to point out the reproduction potential of BSCs which is counted from the eggs number beared by female BSCs (La Sara et al 2010). The fecundity determines the reproductive potential and stock size. The fecundity or the eggs number produced is usually directed to the size of individual (Kumar et al 1999). The fecundity found in the present study ranged from 763,000 to 2,868,284 eggs quite high compared to fecundity found in northern Persian Gulf of 277,421–1,114,348 eggs (Kamrani et al 2010) and in South Australia waters of 650,000–1,760,000 eggs (Kumar et al 2000). The relationship of F and CW follows exponential model of $F = 80443e^{0.0236*CW}$ (r = 0.7679). A previous study conducted in the same location were found fecundities ranging 750.595–1.451.744 following exponential model of $F = 801.817e^{0.0043\ CW}$ (r = 0.9153) (La Sara et al 2010). Those models of relationship of F and CW are different with Mantelatto & Fransozo (1997), Kumar et al (2000), and Ravi et al (2008). Mantelatto & Fransozo (1997) have reported that F of *Callinectes ornatus* increased with an increase in CW. Kumar et al (2000) found out that the F of BSCs increased allometrically with increasing CW, while Ravi et al (2008) reported a significant positive linear relationship with high R^2, while Kumar et al (2000) stated that fecundity is size-dependent. Fecundity increased by 83.9% with an increase of CW from 10.5 cm to 12.5 cm. However, the present study is quite similar with the study on blue crab *Paralithoides platypus* in Alaska which its F increased with increasing CW sizes at a diminishing rate, that is, the relationship is curvilinear (Somerton & MacIntosh 1983). In *Scylla serrata*, there was a wide range in the number of eggs carried by female of any given CW and the range increased allometrically with CW (La Sara et al 2002). Comparing to other studies conducted in Lasongko Bay of Southeast Sulawesi waters (Wangsaatmaja 2007; Sanitha 2007) also showed fecundity variations. Therefore, those results of studies explained that fecundities of the same species and eventhough from the same waters, aside were affected by CW sizes (age) and body weight also were affected by many factors such as seasons which in turn affecting food availability and water quality particularly temperature and salinity. The same explanation also was elucidated by Arshad et al (2006).

La Sara et al (2010) stated that large CW size and body weight of BSCs have not always had larger fecundity, likewise on the contrary. It could be discussed that ovigerous female BSCs in the certain periods is not determined by its CW sizes or body weight. Ovigerous female BSC producing eggs are mostly determined by gonad maturity which may happen on variation of CW sizes or body weights. De Lestang et al (2003b) explained that in the several cases of multiple spawners of larger BSCs may release its eggs of two or more “batches of eggs” in a period of spawning. The fact showed by de Lestang et al (2003b) that an analysis of total F on a beared eggs blue crab individual at the time caught become bias estimation if a blue crab individual had multiple spawns. Due to a researcher did not know whether the eggs in a batch of blue crab individual had been released or not yet released from its body that determining a total of F of BSC individual should be given an explanation that the fecundity found constitutes the fecundity at the time of BSC female caught. Therefore, this fecundity found is not figuring a real total fecundity. This statement is addressed to avoid a bias or mistaken estimation of total fecundity of BSC and another blue crab individual which perhaps those crab samples have released eggs more than once so that its total fecundity is not exactly known.

Eventhough, the entire BSCs include an organism producing more eggs (more fecund). The high egg mass production of BSCs as well as mud crab *S. serrata* could be related to the reproductive strategy (La Sara et al 2002), which is hoped to produce greater offspring, to compensate for the pitfalls from unfavorable environment and to sustain its population.

The first maturity of BSC. The first size maturity of both sexes was determined from CW ranging 7.6–16.3 cm for males and 7.2–15.9 cm for females. Figure 4 shows a logistic curve fitted the estimation of CW_{50} against cummulative frequency of BSCs. The CW of male and female found are 11.957 cm and 10.802 cm, respectively. Safaie et al (2013) showed sexual maturity (CW_{50}) of females is 11.3 cm. De Lestang et al (2003b) showed that the first (gonad) maturity of both sexes BSCs obtained from five west coast waters of Australia having relative different values (Table 2). The CW_{50} size of male BSCs is higher than that of female BSCs obtained from Shark Bay and Koombana Bay. This phenomenon is quite similar with the present study. However, if there are differences of the first maturity that it could be caused by their growth rates which are dependent on seasons and geographical positions. This may be related with the availability of natural diet and other environmental factors (La Sara et al 2002). Safaie et al (2013) stated that CW sizes of BSCs which reach sexual maturity (CW_{50})vary depending on growth rate, which is a direct function of temperature. The CW50 of both males and females in Cockburn, Australia reach sexual maturity at 97 mm CW, while in India CW_{50} size of female was estimated at 96 mm CW (Dineshbabu et al 2008) and in the Philippines females reach sexual maturity at 106 mm CW (Sukumaran & Neelakantan 1997).

Table 2

The first maturity (CW_{50}) of *P. pelagicus* obtained from west coast of Australia (de Lestang et al 2003b) and Southeast Sulawesi waters (present study)

No.	*Location*	*First gonad maturity (CW_{50})*	
		Male	*Female*
1	Leschenault Estuary	87.2 mm	98.0 mm
2	Peel-Harvey Estuary	86.2 mm	97.5 mm
3	Shark Bay	96.0 mm	92.0 mm
4	Koombana Bay	87.1 mm	86.9 mm
5	Cockburn Sound	86.2 mm	86.4 mm
6	Southeast Sulawesi waters (present study)	119.57 mm	108.02 mm

The intensive studies of BSCs caught and covering a width locations in Southeast Sulawesi waters need to be conducted to know why the first maturity (CW_{50}) of male is higher than that of female. However, it is known that all samples of BSCs were caught at inshore around intertidal waters. Generally, female BSCs beared eggs will migrate to offshore having high salinity to release their eggs. This phenomenon has an implication that bigger CW of female BSCs (mature) in estuary will decrease in number and leave behind the small sizes (immature). De Lestang et al (2003b) explained that female gonad weight obtained from the sea was higher than that obtained from estuary. It indicates that females tend to emigrate from estuary to offshore just before its gonad full developed, while all male individuals (including mature BSCs) and female immature remain in estuary waters.

Although the first maturity of both sexes BSCs differs according to the regions but the CW sizes of the first maturity (CW_{50}) of BSCs in the present study have indicated that exploitation of BSCs with CW sizes less than 11.957 cm for male and 10.802 cm for female have to be banned to allow them reaching maturity sizes and having opportunity to spawn then producing zoea in order to maintain its population from threatening intensive exploitation and adverse of waters environment.

Sex ratio of BSC. There are several factors affecting sex ratio on crustacea. La Sara et al (2002, 2010) gave a width explanation regarding disparity in sex ratio. It might result from seasons, locations, differential life span, migration, food availability, methods of capture and fishing gears used, growth and mortality rates are factor known affecting sex ratio of crustacea. Reproduction activities may also affect sex ratio (Kumar et al 2000). Natural mortality (predation, diseases, environment pollution, extreme seasons, and food availability) and fishing mortality in the entire population are much reasonable accepted affecting sex ratio (La Sara 2001a). The other factors affecting sex ratio were growth rate of female crabs slower than those of female, particularly when they attain maturity sizes (La Sara 2001a; Xiao & Kumar 2004). The migration to sea water caused the number of female BSCs in estuarine waters much smaller compared to males. However, changes in feeding behavior of female BSCs during spawning seasons could reduce attractiveness of female BSCs to eat bait in the traps (Kumar et al 2000; La Sara 2001a).

There are some evidences indicating biased sex ratio of *S. serrata* and others Portunid such as La Sara (2001b) found out in Southeast Sulawesi waters that sex ratio (male: female) of *S. serrata* and *S. tranquebarica* were 7.25:1 and 1.14:1, respectively. In the same location in 2002 sex ratio of males *S. serrata* always preponderated over females. Those results are relatively different with the result of the present study on BSCs whereas female BSCs preponderates over males. Similar results on BSCs were reported by Ingles (1996) using gillnet in Bantayan waters, Philippines that sex ratio of male and female was 1:1.63. However, disparity of sex ratio is difficult to explain and could be the difference in the gillnet catchability between sexes (Ingles 1996). It could be also related to behavior of both male and female differ when they attain maturity. Xiao & Kumar (2004) detected yearly variation of male BSCs caught at the off southern commercial waters of Australia decreased and then increased in the later seasons. The BSCs caught by fishermen were mostly male with large CW. Other observation showed that male BSCs catches increased following increasing its CW.

The effect of seasons on BSCs or other Portunids distribution results a season migration. There are juveniles BSCs occupy adjacent mangrove with muddy substrates reaching maturity sizes of 8–10 months (La Sara et al 2016a, b). The female BSCS starting beared eggs (ovigerous) of 1 year old leave inshore to release eggs in offshore (saline waters) (Potter & de Lestang 2000; de Lestang et al 2003b), while the small one still inhabit at the shallow waters. This is partly responsible for a low percentage of female BSCs in estuarine waters. Similar study showed that size distribution on American blue crab *Callinectes sapidus* related to the salinity fluctuation (Archambault et al 1990; Ault et al 1995). Water temperature may also affect feeding behavior and activities searching for food leading to the fishing gears rely on bait (such as traps) or migration of BSCs (gillnets) will catch small number. Sex ratio variation may be also affected by fishing gears used (Xiao & Kumar 2004). The sampling BSC using trap or pots may cause BSCs in the traps or pots die due to attack of aggressiveness of large size BSCs – when they enter in traps or pots that the large size BSC will attack the small one.

Conclusions. The allometric growth pattern of BSCs and the strategy of sustaining its population have to produce eggs in larger number (fecund) of 763,413–2,868,284 eggs. The relationship of F and CW follows the exponential equation with strong correlation (r = 0.7679). The BSCs should be known as a “multiple spawners” in a spawning season so estimation of fecundity at time of sampling is a relative fecundity. Both sexes of BSCs attain size maturity at 11.957 cm CW for males and 10.802 cm CW for females, respectively and should be banned to be caught. Smaller CW sizes than those of CW sizes should be allowed to reaching mature and producing eggs and zoea in order to sustain its population from threatening intensive exploitation and adverse of waters environment. Sex ratio in the present should be maintained due to female BSCs preponderate over male. The ratio gives opportunity to males to mate more than one female.

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References

Archambault J. A., Wenner E. L., Whitaker J. D., 1990 Life history and abundance of blue crab, *Callinectes sapidus* Rathbun, at Charleston Harbor, South Carolina. Bulletin of Marine Science 46:145-158.

Aiken D. E., 1980 Molting and growth. In: The biology and management of lobsters. Vol. I: Physiology and behavior. Cobb J. S., Phillips B. F. (eds), Academic Press, New York, pp. 91-163.

Arshad A., Efrizal, Kamarudin M. S., Saad C. R., 2006 Study on fecundity, embryology and larval development of blue swimming crab *Portunus pelagicus* (Linnaeus, 1758) under laboratory conditions. Research Journal of Fisheries and Hydrobiology 1(1):35-44.

Ault J. S., Patrick E. V., Rothschild B. J., 1995 Physical factors affecting recruitment and abundance of the Chesapeake Bay blue crab stock. Bulletin of Marine Science 57: 917.

Balasubramanian C. P., Suseelan C., 1998 Reproductive biology of the female deepwater crab *Charybdis smithii* (Brachyura: Portunidae) from the Indian Seas. Asian Fisheries Science 10:211-222.

Basri M. I., 2016 [Aspects of reproductive biology as a basis of blue swimming crab (*Portunus pelagicus*, Linn 1758) management in Toronipa waters, Konawe]. MSc thesis, Halu Oleo University, Kendari, 121 pp. [in Indonesian]

de Lestang S., Hall N., Potter I. C., 2003a Influence of a deep artificial entrance channel on the biological characteristics of the blue swimmer crab *Portunus pelagicus* in a large microtidal estuary. Journal of Experimental Marine Biology and Ecology 295:41-61.

de Lestang S., Hall N. G., Potter I. C., 2003b Reproductive biology of the blue swimmer crab (*Portunus pelagicus*, Decapoda: Portunidae) in five bodies of water on the west coast of Australia. Fishery Bulletin 101:745-757.

Dineshbabu A. P., Shridhara B., Muniyappa Y., 2008 Biology and exploitation of the blue swimmer crab, *Portunus pelagicus* (Linnaeus, 1758), from South Karnataka Coast, India. Indian Journal of Fisheries 55(3):215-220.

Edgar G. J., 1990 Predator-prey interaction in seagrass beds. II. Distribution and diet of the blue manna crab *Portunus pelagicus* Linnaeus at Cliff Head, Western Australia. Journal of Experimental Marine Biology and Ecology 139:23-32.

Hancock D. A., Edwards E., 1967 Estimation of annual growth in the edible crab (*Cancer pagurus* L.). J Cons Perm Int Explor Mer 31(2):246 – 255.

Ingles J. A., 1996 The crab fisheries off Bantayan, Cebu, Philippines. IMFO-CF, University of the Philippines – PCMARD, Philippines, 88 pp.

Kamrani E., Sabili A. N., Yahyavi M., 2010 Stock assessment and reproductive biology of the blue swimming crab, *Portunus pelagicus* in Bandar Abbas coastal waters, Northern Persian Gulf. Journal of the Persian Gulf (Marine Science) 1(2):11-22.

Kangas M. I., 2000 Synopsis of the biology and exploitation of the blue swimmer crab, *Portunus pelagicus* Linnaeus, in Western Australia. Fisheries Research Report No. 121, Fisheries Western Australia, Perth, Australia, 22 pp.

Knuckey I. A., 1996 Maturity in male mud crabs, *Scylla serrata* and the use of mating scars as a functional indicator. Journal of Crustacean Biology 16(3):487-495.

Kumar M. S., Xiao Y., Williams K., Ferguson G., Venema S., 1999 Blue crab-assessment update and review of biological indicators and reference points. South Australian fisheries assessment series 99/2, SARDI, 78 pp.

Kumar M., Ferguson G., Xiao Y., Hooper G., Venema S., 2000 Studies on reproductive biology and distribution of the blue swimmer crab (*Portunus pelagicus*) in South Australian waters. South Australian Research and Development Institution (SARDI), Australia, 35 pp.

La Sara, 2001a Ecology and fisheries of mud crab *Scylla serrata* in Lawele Bay, Southeast Sulawesi, Indonesia. PhD Dissertation, University of the Philippines in the Visayas, 198 pp.

La Sara, 2001b Habitat and some biological parameters of two species of mud crab *Scylla* in Southeast Sulawesi, Indonesia. In: Proceeding of the JSPS-DGHE International Symposium on Fisheries Science in Tropical Area. Carman O., Sulistiono, Purbayanto A., Suzuki T., Watanabe S., Arimoto T. (eds), TUF International JSPS Project Vol. 10, Konan Minato-ku, Tokyo, Japan, pp. 341-346.

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.

La Sara, Astuti O., 2011 [The reproductive biology of blue crab *Portunus pelagicus* (Brachyura: Portunidae) in Lasongko Bay, Southeast Sulawesi, Indonesia]. Research Institution of Halu Oleo University, Kendari, 88 pp. [in Indonesian]

La Sara, Astuti O., 2015 [Harvest control rule for blue swimming crab (*Portunus pelagicus*) in Southeast Sulawesi waters]. Proceeding of the 2nd Fishery and Marine National Symposium, pp. 263-270. [in Indonesian]

La Sara, Ingles J. A., Baldevarona R. B., Aguilar R. O., Laureta L. V., Watanabe S., 2002 Reproductive biology of mud crab *Scylla serrata* in Lawele Bay, Southeast Sulawesi, Indonesia. Proceeding of the JSPS-DGHE International Seminar on Fisheries Science in Tropical Area. Crustacean Fisheries, pp. 88-95.

La Sara, Hamid A., Safilu, 2010 [Study on ecology and population dynamics of blue swimming crab (*Portunus pelagicus*) in Lasongko Bay, Buton]. Research and Community Service Institution of Halu Oleo University, Kendari, 78 pp. [in Indonesian]

La Sara, Muskita W. H., Astuti O., 2014 [Blue swimming crab (*Portunus pelagicus*) fisheries management design to sustain its population and to increase fishermen income in Southeast Sulawesi waters of Indonesia. Part I: Habitat characteristics and relative abundance of blue swimming crab]. Research and Community Services Institution, Halu Oleo University, Kendari, 96 pp. [in Indonesian]

La Sara, Muskita W. H., Astuti O., 2015 [Mapping fishing ground of blue swimming crab (*Portunus pelagicus*) in Tiworo Strait, Southeast Sulawesi, Indonesia]. A research report of MP3EI, Research and Community Service Institution of Halu Oleo University, Kendari, 91 pp. [in Indonesian]

La Sara, Halili, Mustafa A., Bahtiar, 2016a Appropriate escape vent sizes on collapsible crab pot for blue swimming crab (*Portunus pelagicus*) fishery in southeast Sulawesi waters, Indonesia. Journal of Fisheries and Aquatic Sciences, DOI: 10.3923/jfas.2016.

La Sara, Muskita W. H., Astuti O., Safilu, 2016b Effort in harvest control for blue swimming crab (*Portunus pelagicus*) in Southeast Sulawesi, Indonesia. Paper presented in the Crustacean Society Mid-Year Meeting 2016, National University of Singapore, Singapore, 11-13 July 2016.

La Sara, Muskita W. H., Astuti O., Safilu, 2016c [Reproductive biology and fishing control of blue swimming crab (*Portunus pelagicus*) in Southeast Sulawesi waters, Indonesia]. Paper presented in the 3th Fishery and Marine National Symposium, Makassar, 7 May 2016. [in Indonesian]

Mantelatto F. L. M., Fransozo A., 1997 Fecundity of the crab *Callinectes ornatus* Ordway, 1863 (Decapoda, Brachyura, Portunidae) from the Ubatuba region, Sao Paulo, Brazil. Crustaceana 70:214-226.

Meagher T. D., 1971 Ecology of the crab *Portunus pelagicus* (Crustacea: Portunidae) in South-western Australia. PhD thesis, University of Western Australia, 462 pp.

Muchtar A. S., 2016 [Some population parameters of blue swimming crab (*Portunus pelagicus*, Linn 1758) in Toronipa waters, Konawe]. MSc thesis, Halu Oleo University, Kendari, 76 pp. [in Indonesian]

Permatahati Y. I., 2016 [Reproductive biology and ecology of blue swimming crab (*Portunus pelagicus*) in Bungin Permai waters, Southeast Sulawesi]. MSc thesis, Halu Oleo University, Kendari, 125 pp. [in Indonesian]

Phillips B. F., Cobb J. S., George R. W., 1980 General biology. In: The biology and management of lobsters. Vol. I: Physiology and behavior. Cobb J. S., Phillips B. F. (eds), Academic Press, New York, pp. 1-82.

Potter I. C., de Lestang S., 2000 Biology of the blue swimmer crab *Portunus pelagicus* in Leschenault estuary and Koombana Bay, South-western Australia. Journal of the Royal Society of Western Australia 83: 443-458.

Potter M., Sumpton W., Smith G., 1987 Queensland sand crab study highlights a need for changes in management. Australian Fisheries 46(6):22-26.

Prasad R. R., Tampi, P. R. S., 1953 A contribution to the biology of the blue swimming crab *Neptunus pelagicus* (Linnaeus) with a note on the zoea of *Thalamita crenata* Latreille. J Bombay Nat Hist Soc 51:674-689.

Ravi R., Manisseri M. K., Kuriakose S., 2008 Relationship between morphometric characteristics and fecundity of *Portunus pelagicus* (Linnaeus, 1758). Journal of the Marine Biological Association of India 50(2):217-220.

Risnawaty, 2003 [Study on some biological aspects of blue swimming crab (*Portunus pelagicus*) in Purirano coastal waters of Kendari City, Southeast Sulawesi (Part II: February – April 2013)]. BSc thesis, Department of Fisheries, Faculty of Agricultural, Halu Oleo University, Kendari, 77 pp. [in Indonesian]

Safaie M., Pazooki J., Kiabi B., Shokri M. R., 2013 Reproductive biology of blue swimming crab, *Portunus segnis* (Forskal, 1775) in coastal waters of Persian Gulf and Oman Sea. Iranian Journal of Fisheries Sciences 12(2):430-444.

Sanitha I., 2007 [Study on fishing variation of blue swimming crab (*Portunus pelagicus*) in Lasongko Bay of Buton, Southeast Sulawesi]. BSc thesis, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kendari, 69 pp. [in Indonesian]

Sawusdee M. A., Songrak A., 2009 Population dynamics and stock assessment of blue swimming crab (*Portunus pelagicus,* 1758) in the coastal area of Trang Province, Thailand. Walailak Journal of Science and Technology 6(2):189-202.

Somerton D. A., MacIntosh R. A., 1983 The size at sexual maturity of blue king crab, *Paralithodes platypus* in Alaska. Fishery Bulletin 81(3):621-628.

Sudjana, 1989 [Statistics method]. Tarsito, Bandung, 508 pp. [in Indonesian].

Sukumaran K. K., Neelakantan B., 1997 Age and growth in two marine portunid crabs, *Portunus* (*Portunus*) *sanguinolentus* (Herbst) and *Portunus* (*Portunus*) *pelagicus* (Linnaeus) along the south-west coast of India. Indian Journal of Fisheries 44:111-131.

Sunarto, 2012 [Bioecology characteristics of blue swimming crab (*Portunus pelagicus*) in Brebes waters]. MSc thesis, Postgraduate School, Bogor Agricultural University, Bogor, 143 pp. [in Indonesian]

Sutriani, 2002 [Study on some biological aspects of blue swimming crab (*Portunus pelagicus*) in Purirano coastal waters of Kendari City, Southeast Sulawesi]. BSc thesis, Department of Fisheries, Faculty of Agricultural, Halu Oleo University, Kendari, 84 pp. [in Indonesian]

Syarif N., 2007 [Size composition and relative abundance of blue swimming crab (*Portunus pelagicus*) in Lasongko Bay of Buton, Southeast Sulawesi]. BSc thesis, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kendari, 64 pp. [in Indonesian]

Tongdee N., 2001 Size distribution, sex ratio and size at maturity of mud crab (*Scylla* spp) in Ranong Province, Thailand. Asian Fisheries Science 14:113-120.
Wangsaatmaja H., 2007 [Study on habitat and abundance of blue wimming crab (*Portunus pelagicus*) in Lasongko Bay of Buton, Southeast Sulawesi]. BSc thesis, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kendari, 59 pp. [in Indonesian]
Xiao Y., Kumar M., 2004 Sex ratio and probability of sexual maturity of females at size of the blue swimmer crab, *Portunus pelagicus* Linnaeus, off Southern Australia. Fisheries Research 68:271-282.

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Authors:
La Sara, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kampus Bumi Tridharma, Kendari 93232, Southeast Sulawesi, Indonesia, e-mail: lasara_unhalu@yahoo.com
Wellem H. Muskita, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kampus Bumi Tridharma, Kendari 93232, Southeast Sulawesi, Indonesia, e-mail: wmuskita@yahoo.com
Oce Astuti, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kampus Bumi Tridharma, Kendari 93232, Southeast Sulawesi, Indonesia, e-mail: oce-fish@yahoo.com
Safilu, Department of Biology, Faculty of Education, Halu Oleo University, Kampus Bumi Tridharma, Kendari 93232, Southeast Sulawesi, Indonesia, e-mail: safiluimaluddin@yahoo.com

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