Some population parameters of blue swimming crab (*Portunus pelagicus*) in Southeast Sulawesi waters, Indonesia

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Abstract. The blue swimming crab (*Portunus pelagicus*) population in Southeast Sulawesi waters had decreased sharply, while study on it has been neglected. This study determined carapace width (CW) composition, mortality (Z, F and M), yield per recruit (Y/R') and exploitation rate (E). Monthly samples were obtained using baited crab traps and gillnets. All samples were separated according to the sex, where each of them was measured its CW and weighed its wet body weight. Growth parameters (CW_∞, K), Z, F, M and Y/R' were analyzed using the ELEFAN II method. The results showed CW size varied between 2.00-16.00 mm. CW of 4.00 – < 10.00 mm were dominant, while CW of ≥ 10.00 mm was very limited and in some zones were not found. The K of males ($K/_{year}$ = 1.30) was higher than that of females ($K/_{year}$ = 0.55), while CW_∞ of males (CW_∞ = 140.93 mm) was slightly smaller than that of females (CW_∞ = 149.26 mm). It was followed by total mortality of males (Z = 4.11) which was much higher than that of females (Z = 0.79). Natural mortality (M) contribution of males and females to Z were 33.3% and 97.5%, respectively which was partially due to CW_∞ and K. The Y/R' optimum could be achieved with reducing number of fishermen and fishing gears because the E = 0.668 had showed an over-exploited. Those problems could be overcome through management action of its population and habitat.

Key Words: *Portunus pelagicus*, carapace width composition, growth parameters, mortality, yield per recruit, exploitation rate.

Introduction. Blue swimming crabs (BSCs, *Portunus pelagicus*) are reportedly widespread throughout the Indo-West Pacific regions so that it forms a major component of commercial fisheries in those regions (Lai et al 2010; La Sara et al 2016a, b). BSCs live in shallow coastal and estuarine waters with sand substratum of lagoon, including surrounding of mangrove, seagrass and algae beds. The BSCs are usually found at water depth of < 1 m up to 50 m in the entire of India and Indo-West Pacific from Japan, Philippines, Malaysia, Brunei Darrusalam, Indonesia, eastern Australia and Fiji Island, Red Sea and East Africa (Stephenson 1962; Williams 1982; Edgar 1990; Potter & de Lestang 2000; Johnston et al 2011; La Sara et al 2016b). In Southeast Sulawesi waters, the BSC is one of the dominant species distributed throughout the coastal sea usually in the intertidal zones up to water depth of 30 m (La Sara & Astuti 2011; La Sara et al 2014, 2015, 2016a, b; Muskita et al 2015) and to be one of the most important species for small-scale fisheries. Generally, juveniles occupy intertidal zones close to mangroves (La Sara et al 2014, 2016a, b), while carapace width (CW) of > 8 cm are caught at water depth of > 20 m.

BSCs in Southeast Sulawesi waters had been exploited since last 3 decades, but intensive exploitation was started last 2 decades when consumers demand increased sharply. Gillnets and crab pots are commonly used by fishermen to catch BSCs leading to its population decrease dramatically and even BSCs population in some places are already disappeared (La Sara et al 2014, 2015, 2016a). Several studies showed that BSCs caught at several fishing grounds had CW of < 6 cm. In other fishing grounds, the number of BSCs caught also showed a decreasing trend (Sanitha 2007; Wangsaatmaja

2007; La Sara et al 2016a, b, c), fishing ground moved afield, and very rare found at the initial of its habitats (La Sara et al 2014, 2016a, b). One of the constraints for its population management is that catch data is not well monitored and recorded. This is due to the buyers do not report the actual production of BSCs to the local Fisheries and Marine Affairs Office and the officers in-charge are not able to cover all BSCs landing stations. The study on its ecology and biology in Southeast Sulawesi waters is very rare and only conducted in short period of time, such as fluctuation of catch production, size composition, habitat and abundance, and fishing capture (Mustafa & Abdullah 2013; Permatahati 2016; La Sara et al 2016a, 2016b). There are recent related studies which have been conducted but limited on reproductive biology and ecology (Basri 2016; Permatahati 2016; La Sara et al 2016b) and crab pot selectivity for BSCs (La Sara et al 2016c). The problems are BSCs management right now is not formulated yet, while its population exploitation is very intensive (Muchtar 2016; La Sara et al 2016c). In Australia catching BSCs for commercial and recreation is regulated based on local government regulation.

The study on population parameters of BSCs is very rare conducted and limited in narrow areas around Southeast Sulawesi waters. This study is important to be conducted for its management formulation purpose. To formulate better BSC fisheries management, spatial and temporal time series data should be gathered. The objective of the study was to find out some population parameters of BSCs which consisted of growth coefficient, total mortality, fishing mortality, yield per recruit (Y/R') and exploitation level.

Material and Method

Sampling BSC. The samples of BSCs were collected from June to December 2014 in Tiworo Strait, Southeast Sulawesi. The sampling locations were directly chosen in the BSC fishing grounds which had been exploited by fishermen since years. Those locations were characterized by: (1) intertidal zone which had water depth of 0-30 m, relatively high salinity fluctuation of 23-35 ppt, and dominated by sand substrate (Zone I); (2) inundated sea water located in front of mangrove forest, salinity relatively stable of 34-37 ppt, and substrate of sand mixed with mud (Zone II); (3) grow heavy seagrass (eelgrass), salinity relatively high of > 37 ppt, and substrate of sand mixed with mud (Zone III); (4) overgrown with scarce seagrass, salinity relatively high of > 37 ppt, and substrate of sand mixed with mud (Zone IV); (5) high salinity fluctuation and dominated by mud substrate located at a river mouth (Zone V); and (6) water depth of > 20 m, high salinity of 37-41 ppt, and sand substrate (Zone VI) (Figure 1).

Sampling of BSCs at each zone was undertaken regularly on a monthly basis using baited crab traps and gillnets. The baited crab traps were set at all zones, while gillnets were set at zone VI. The distance between crab traps was ±20 m apart and leaved them for about 10-12 hours. Similarly, gillnets were set once in the zone VI with water depth of > 20 m. The catches of BSCs from each zone and month were recorded according to its sex, measured to the nearest 0.1 mm as to its carapace width (CW) using a caliper, and wet weighed to nearest 1 g using electronic balance (CAMRY EK 5055 Max 5 KG) (La Sara 2001, 2010; La Sara et al 2016b, c).

Data analysis. The catches data of each sex from each zone were analyzed based on CW, growth parameters (C_∞, K), total mortality (Z), fishing mortality (F), natural mortality (M), and yield per recruitment (Y/R'). Size compositions of both sexes were analyzed in term of CW frequency distribution, while the growth parameters (C_∞, K) of each sex from all zones were analyzed using the growth function of von Bertalanffy as follows:

$$CWt = CW\infty\{1 - e^{-K(t-to)}\}$$

where CW_t is CW at t age, CW_∞ is CW infinity or asymptotic CW, t is age, t_0 is age at t is 0, and K is curvature growth constant, and e is exponential.

Those growth parameters together with Z, F and Y/R' were derived from CW frequency table generated from gear catches and were computed using the ELEFAN II method as incorporated in the FISAT program (Gayanilo et al 1996). Those equations had been used by La Sara (2010) to analyse size structure and population parameters of mud crab *Scylla serrata* in Lawele Bay.

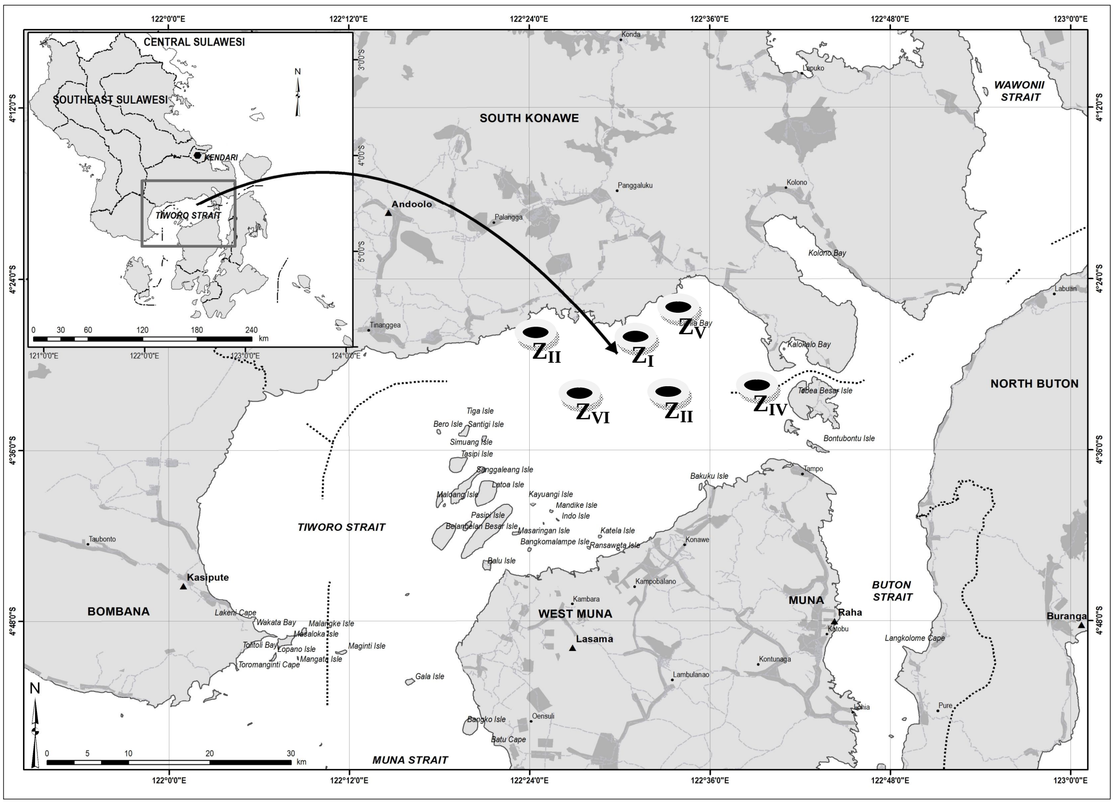

Figure 1. Map of location of sampling BSCs (*P. pelagicus*) in Tiworo Strait, Southeast Sulawesi, Indonesia (Z_{I-VI} = Zone I–VI).

Results

Size composition of carapace width. Size composition frequency of CW of BSCs based on spatial and temporal distributions are presented in Figures 2 and 3. Spatial and temporal distribution of each sex were established based on combined catch data of each month and catch data of each zone, respectively. During the study, the CW sizes were measured from the entire zones ranged from 2.0 to 15.99 cm. The CW frequency of BSCs caught monthly showed that CW of < 9.99 cm were dominat. In general, those sizes were classified into juvenile and mature stages (Figure 2) which were generally caught at Zone I and Zone II (Figure 3).

Growth parameters. The CW frequency distribution of both males and females were analyzed using ELEFAN II (Gayanilo et al 1996) resulting the von Bertalanffy growth parameters of CW_∞ and K (Table 1). This method had been used to analyze growth parameters of BSCs caught in Bantayan, Philippines (Ingles 1996), mud crab *Scylla serrata* caught in Lawele Bay, Southeast Sulawesi (La Sara 2001, 2010), and mud crab *S. serrata* caught in Bangladesh (Zafar et al 2006).

Table 1

Growth parameters of male and female BSCs in Tiworo Strait, Southeast Sulawesi, Indonesia

Parameter	*Male*	*Female*
$CW_{\infty\ (mm)}$	160.93	169.26
$K_{(/month)}$	1.30	0.55

Note: CW = carapace width; K = curvature growth constant.

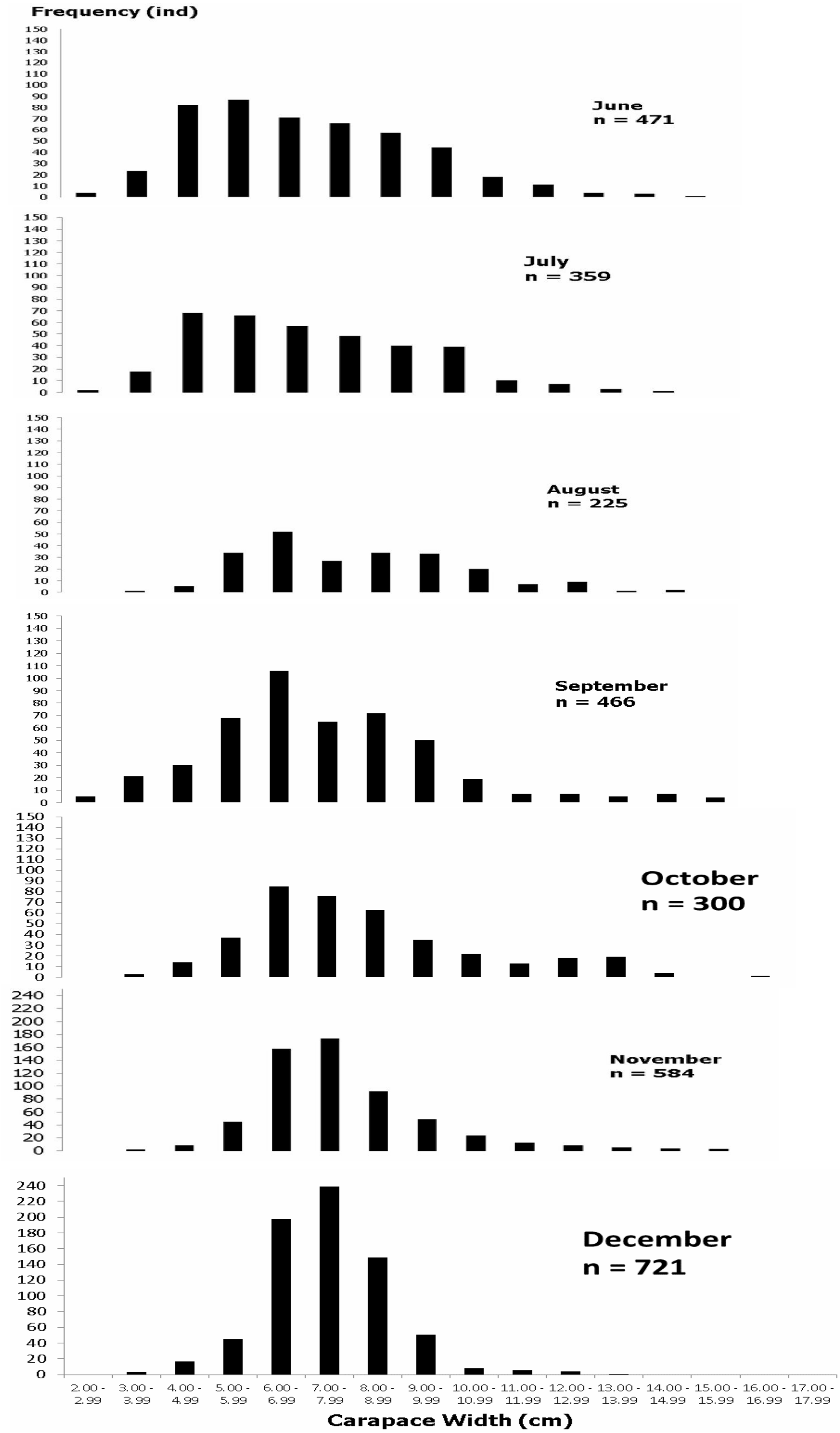

Figure 2. Carapace width frequency of BSCs based on temporal distribution caught using gillnets and traps in Tiworo Strait, Southeast Sulawesi, Indonesia (catch data from each zone combined).

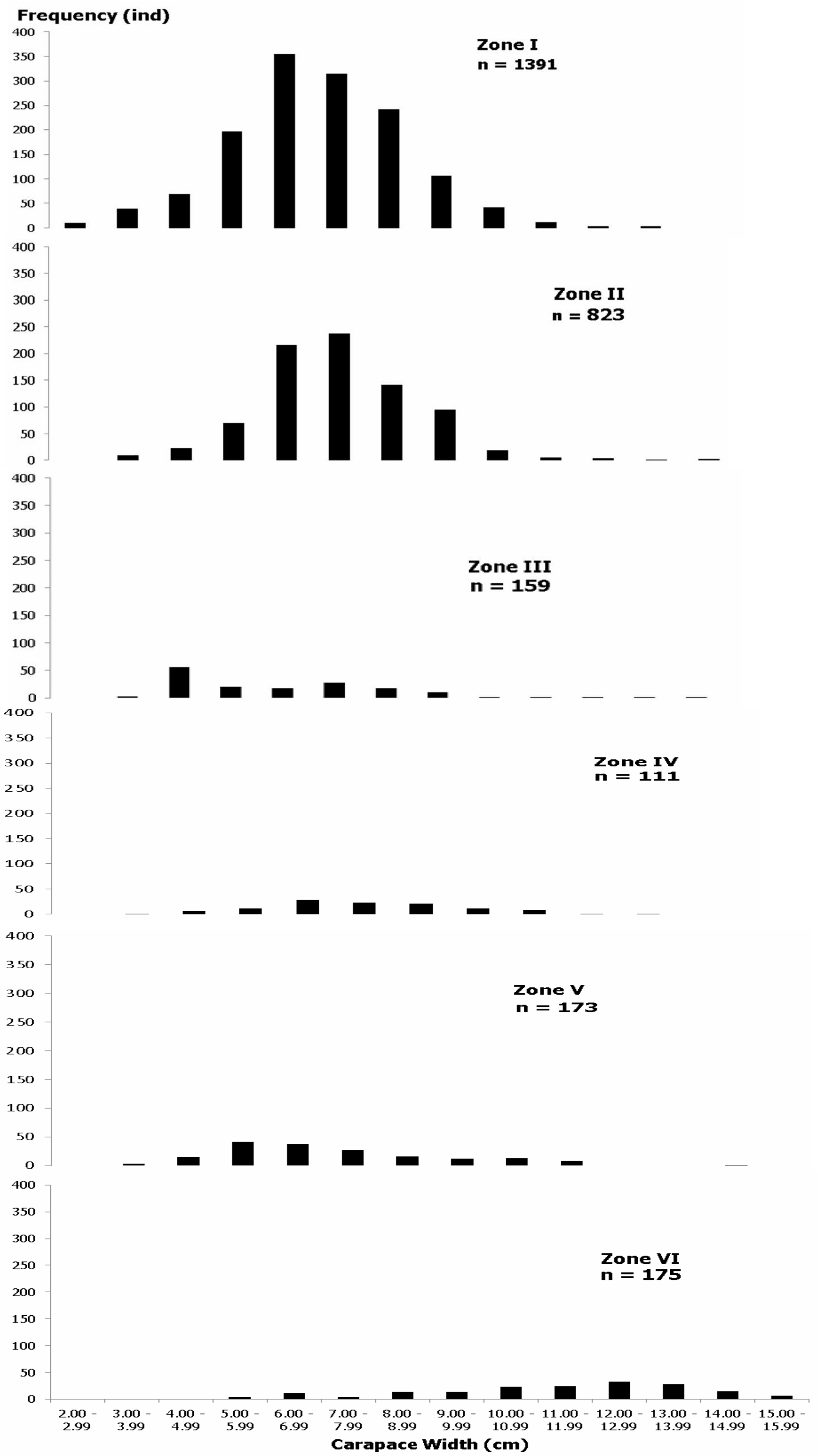

Figure 3. Carapace width frequency of BSCs based on spatial distribution caught using gillnets and traps in Tiworo Strait, Southeast Sulawesi, Indonesia (catch data from each location combined).

Estimation of mortality. The estimate of total mortality (Z) of both male and female sexes is computed using the length-converted catch curve under assumption that population of BSCs is steady state condition (Figure 4). The Z value of male BSCs is smaller than that of female BSCs (Table 3). Similar trend was found in the estimate of natural mortality (M) which was computed using the Pauly's empirical equation.

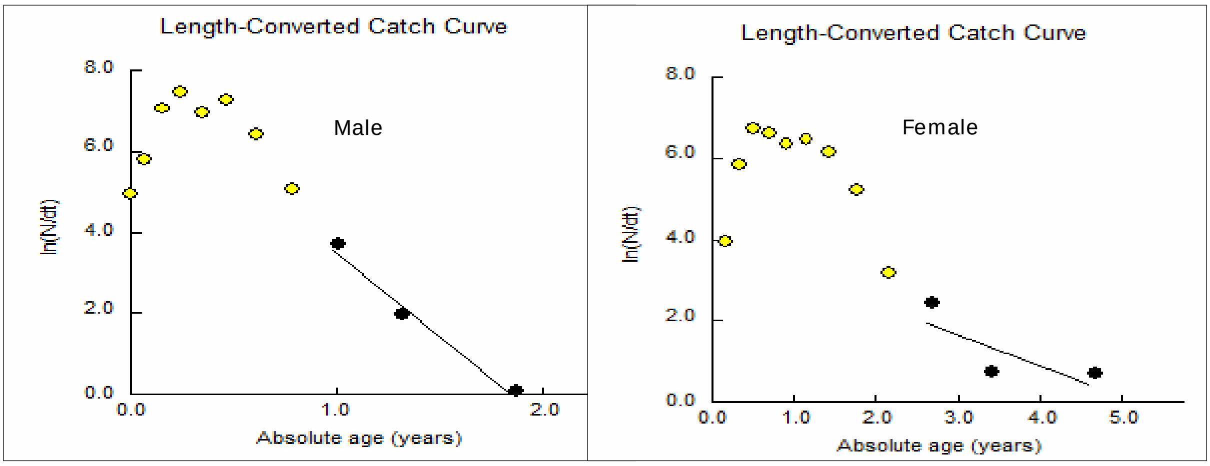

Figure 4. Estimate of total mortality (Z) of male (left) and female (right) BSCs in Tiworo Strait, Southeast Sulawesi, Indonesia using "The Length Converted Catch Curve Method" (only black polygon dot used in regression).

Relative yield per recruit (Y'/R). BSCs recruitment patterns of both male and female sexes in Southeast Sulawesi waters are found all year round The data collected showed that the peak recruitment of males and females was in June and then went down up to September (Figure 5). It seems that recruitment patterns of both sexes were simultaneously with sex ratio change namely female BSCs usually preponderated over males. The relative value of Y'/R Beverton & Holt model (1966) uses a "knife edge".

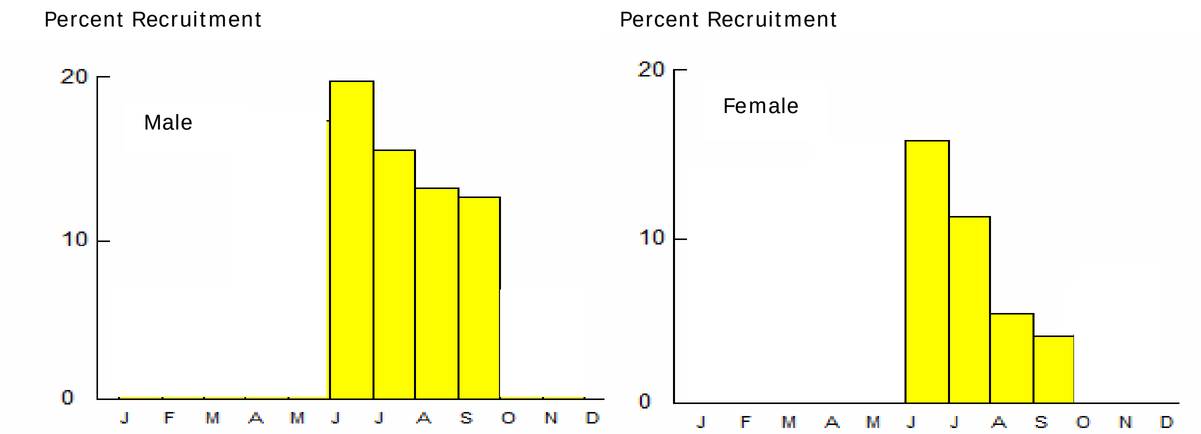

Figure 5. Recruitment patterns of male (left) and female (right) BSCs based on temporal distribution in Tiworo Strait, Southeast Sulawesi, Indonesia (catch data of each month from all location combined).

The value of maximum exploitation rate (E_{max}) of each male and female BSCs were 0.415 and 0.391, respectively resulting in respective of males and females Y'/R of < E_{50} (E_{50} = 0.06) (Figure 6). Those values were found based on the CW first size caught (t_c) of both male and female sexes of 74 mm. If this data is simulated that the CW first size caught (CW_c) is increased to be 89 mm that the Y'/R value of both male and female sexes is apparent slightly different with the former value (the Y'/R value is to be slightly low) (Figure 7).

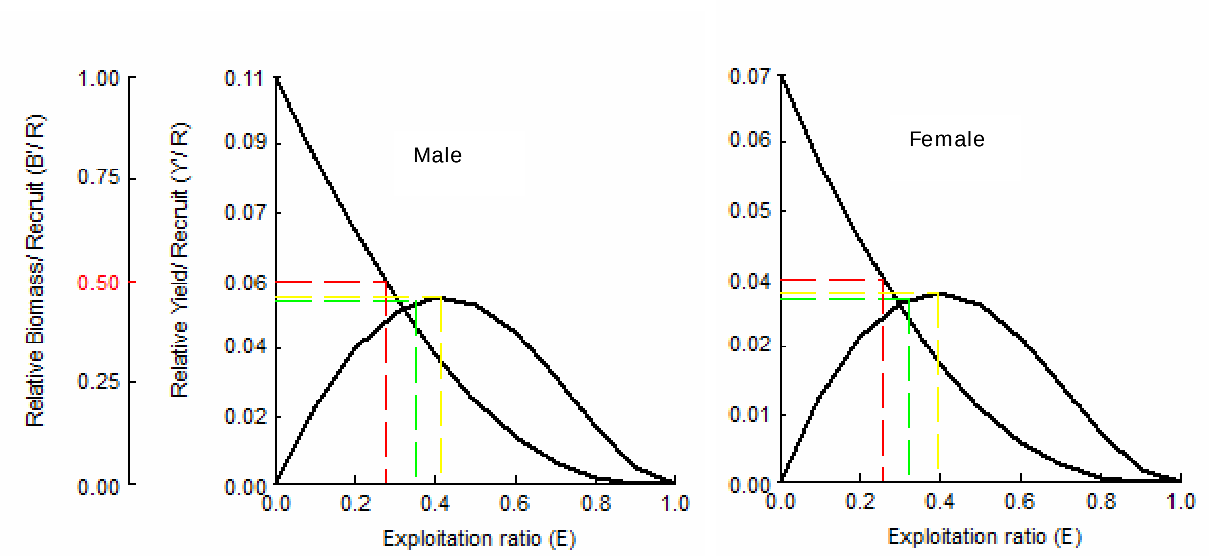

Figure 6. The estimated yield per recruit (Y'/R) Beverton and Holt Model of male (left) and female (right) BCSs (CW_c = 7.4 cm) in Tiworo Strait, Southeast Sulawesi, Indonesia.

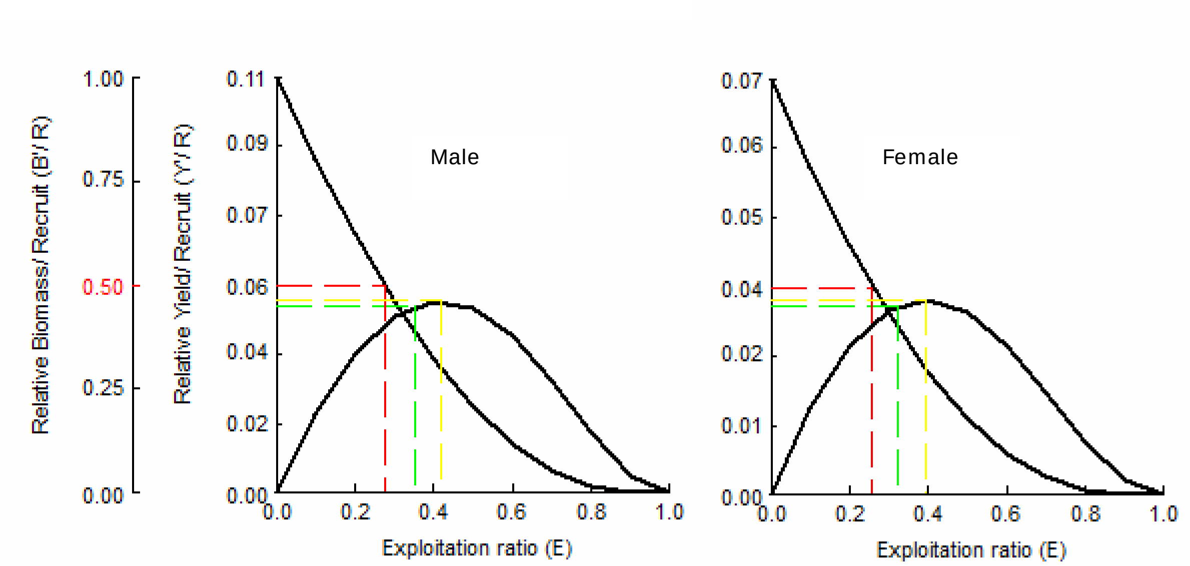

Figure 7. The estimated yield per recruit (Y'/R) Beverton and Holt Model of male (left) and female (right) BSCs (CW_c = 8.9 cm) in Tiworo Strait, Southeast Sulawesi, Indonesia.

Discussion

Size composition of carapace width. The data of CW sizes of Portunidae from different locations around Asian and Australian waters (Table 2) coincided with light body weight of those BSCs in the present study, ranging 10.00-80.00 g. The body weight which was dominant found was < 50.00 g reaching 70-85%. This phenomenon indicated that if fishermen would like to get 1 kg of BSCs body weight that the fishermen have to catch 13-100 BSCs individuals. Those data indicated that the size of BSCs is already very small which are prohibited according to "the Decree of Ministry of Marine Affairs and Fishery of the Republic of Indonesia No. 1/2015". To fulfill daily expenses of a fishermen family, they have to catch BSCs of 2-3 kgs (equivalent to 26-200 individuals). This data constitutes an early warning for stakeholders to take responsibility into regulation of exploitation intensity of BSCs around Southeast Sulawesi waters. Its management should be formulated with care in order to sustain population of BSCs. This threatening is found at all waters area (spatial) and at all year round (temporal) of Southeast Sulawesi waters.

Table 2

The von Bertalanffy growth parameters of Portunidae from different locations around Asian and Australian waters (adopted from La Sara 2010)

Location	*Species*	*Sex*	*K*	*$CW_{\infty(mm)}$*	*Source*
Bantayan, Philippines	*P. pelagicus*	Male	0.98	225	Ingles (1996)
		Female	0.70	225	
Mangalore, Malpe and Karwar, India	*P. sanguinolentus*	Male	0.99	195	Sukumaran & Neelakantan (1997)
		Female	0.82	188	
	P. pelagicus	Male	1.14	211	Sukumaran & Neelakantan (1997)
		Female	0.97	204	
Peel-Harvey Estuary, Australia	*P. pelagicus*	Male and female in 1980-1981	3.0	155.7	de Lestang et al (2003)
		Male and female in 1995-1998	1.3	128.9	
Chakaria Sundarban, India	*S. serrata*	Male	0.28	109	Zafar et al (2006)
		Female	0.36	105	
Northern Territory, Australia	*S. serrata*	Male	1.46	152.5	Ward et al (2008)
		Female	0.81	185.4	
Lawele Bay, Indonesia	*S. serrata*	Male	1.38	211	La Sara (2010)
		Female	0.83	210	
Bandar Abbas, Northern Persian Gulf	*P. pelagicus*	Male	1.2	168	Kamrani et al (2010)
		Female	1.1	177.9	
Tiworo Strait, Indonesia	*P. pelagicus*	Male	1.30	160.93	Present study
		Female	0.55	169.26	

The age of the BSCs caught at zones I-V was less than a year which means those sizes have not attained reproductive stage. The juvenile stage seemed higher than mature stage during this period of June-September 2014. This phenomenon clearly showed that matures BSCs caught in the previous months had intensively exploited as it still happens during the present study. All fishing activities were done at inshore waters as it coincided with juvenile and mature stages of BSCs caught at zones I-V (Figure 3). The matured BSCs of ≥ 10 cm were caught in September and October and some in November – December (Figure 2) mainly at zone VI and very few found at the other zones (Figure 3). It indicates that matured size of BSCs moves afield to off shore to spawn and grow (La Sara et al 2014, 2016a). There were matured female BSCs carrying eggs at zone VI. This location has water depth of > 20 m, temperature of 27-33ºC, salinity of 37-41 ppt, and sand substrate which are preferred by female mature BSCs. Fishing of BSCs at zone VI was very rare due to fishing gears used by fishermen were generally crab pots which were operated mainly in intertidal zone (zones I-V). Therefore, the BSCs have opportunity to migrate to spawn in offshore with high salinity (Hill 1994; Potter & de Lestang 2000; Kamrani et al 2010; Sant'Anna et al 2012; La Sara et al 2016b) and grow up attaining matured sizes (La Sara et al 2016b, d). The BSC juveniles and matures stages were dominant at zone I and zone II so those zones actually should be decided as *nursery grounds* for juveniles of BSCs, while at zones III, IV and IV are much frequent caught adult (mature) stage and so those sites are recommended to be feeding grounds.

Growth parameters. The estimation of growth parameters (CW_{∞}) as an input to the ELEFAN II analysis was derived using the Powell-Wetherall's Plot. The K values (Table 1) were obtained from scan of K value that has the highest "Rn" using ELEFAN II. The CW_{∞} of female BSC was higher than that of male BSC, but its curvature growth constant (K) of male BSC is higher than that of female BSC, where it differed around 42.38%. Several studies on portunidae from different location around Asian and Australian waters also showed that K of males is relatively higher than that of K of females (Table 2). In the present study, there were several local fishermen in Tiworo Strait who reported that generally daily BSCs caught of females were bigger than that of males (Table 1).

The nature of BSCs growth and other crustaceans is started by moulting, leading to much difficulty in determining the true growth rate (Zafar et al 2006; La Sara 2010), particularly under natural conditions (Sukamaran & Neelakantan 1997). Generally, the studies on growth of crustacean are conducted in the laboratory condition or kept in tank or cage/pen system (Ong 1966; Lavina1980; Yatsuzuka & Meruane 1987; Millamena & Bangcaya 2001; La Sara 2001; Mwaluma 2002; Mirera & Mtile 2009) and by tagging (Hill 1982; Potter et al 1991; Moser et al 2002; Ward et al 2008). Sukamaran & Neelakantan (1997) constituted growth and age of BSCs (*P. sanguinolentus* and *P. pelagicus*) through a progression of modes of size distribution frequency using catch data. Similarly, La Sara (2010) analyzed for *S. serrata* from Lawele Bay.

The present study results (Table 1) showed that male BSCs grow faster than that of female BSCs, although the data of Mirera & Mtile (2009) showed that males were observed to have similar growth with females. In general the result of growth parameters (CW_∞, K) analysis is slightly different with some results of study on crustacean found in several waters (Table 2). Those data showed that there were differences of CW_∞ and K values of each species due to regional differences (La Sara 2010). The differences of those growth rates may be caused by food availability, temperature and salinity (La Sara 2010). Ingles (1996) stated that the difference in the K between male and female sexes could possibly explain the discrepancy in the sex ratio.

Estimation of mortality. The mortality (Z, M and F) of males is higher than that of females (Table 3). Of about 33.3% was contributed from M for Z males and 97.5% for Z females. The study of La Sara (2010) on mud crab (*S. serrata*) in Lawele Bay described that the higher M value of females was apparent, particularly after mating and during their migration to sea water to spawn, while higher F for males was mostly due to the occupied intertidal flat or shallow waters with high fishing activities. In contrary, there were reports stated that the Z of females is lower than that of males (Dineshbabu et al 2008; Sawusdee & Songrak 2009; Kunsook et al 2014), while other report from Bandar Abbas coastal waters of Northern Persian Gulf stated similar trend mortality of both females and males (Kamrani et al 2010). La Sara (2010) explained that generally male of crab species grow up to bigger size and this condition lead to most vulnerable on fishing activities. In particular, it may be stated that K value may be attributed to the difference of Z between male and female sexes. King (1995) stated that generally M values on both sexes are higher due to predation.

Table 3

Total mortality (Z), natural mortality (M), and fishing mortality (F) of male and female BSCs in Tiworo Strait, Southeast Sulawesi, Indonesia

Parameter	*Male*	*Female*
Z	4.11	0.79
M	1.37	0.77
F	2.74	0.02
E	0.67	0.03

The Z value as well as the M value of male BSCs that higher than that of female BSCs (Table 3) were also found in several other different waters (Table 4). There are several marine environmental factors which act to reduce the chance of survival of individuals in a population. King (1995) described that those were caused by adverse of water quality, lack of food, competition and predation. In several cases, the fishing mortality (F) of crustacean is difficult to be estimated. La Sara (2010) noted that estimating population dynamics on *S. serrata* remains poorly understood as there is few information on mortality which had been done in tropical regions.

Table 4

The total mortality (Z), natural mortality (M) and fishing mortality (F) values of Portunidae from Different Locations (adopted from La Sara 2010)

Location	*Species*	*Sex*	*Z*	*M*	*F*	*Sources*
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	*	*	Sukumaran & Neelakantan (1996)
		Female	2.64	*	*	
	P. pelagicus	Male	6.85	*	*	Sukumaran & Neelakantan (1996)
		Female	5.31	*	*	
Karwar, India	*P. sanguinolentus*	Male	5.22	*	*	Sukumaran & Neelakantan (1996)
		Female	3.84	*	*	
	P. pelagicus	Male	4.29	*	*	Sukumaran & Neelakantan (1996)
		Female	3.55	*	*	
Tiworo Strait, Indonesia	*P. pelagicus*	Male	4.11	1.37	2.74	Present study
		Female	0.79	0.77	0.02	

Note: * = data not available.

Exploitation rate (E) of male BSCs in the present study has been in danger condition as shown by E = 0.67 (Table 3). It indicates that fishing activities are already in over exploitation level. Similar result was also found in other part of Southeast Sulawesi waters namely E = 0.52 for male and E = 0.47 for female (Muchtar 2016). In several tropical regions also show similar phenomenon such as in Karnataka coast of Southwest India (Dineshbabu et al 2008), Persian Gulf and Oman Gulf (Safaie et al 2013) and Bandar Abbas coastal waters of Northern Persian Gulf (Kamrani et al 2010). Those exploitation rates implied that fishing mortality (F) gave high contribution to the total mortality (Z) compared to natural mortality (M). The management effort should be implemented particularly in reducing fishing effort or regulate not to use unselective fishing gear. La Sara et al (2016b) have recommended the use of collapsible crab pot using escape vent size of 5.0 cm x 3.5 cm which are attached in the both right and left sides of the crab pots. The authors explained that BSCs of < 10 cm CW have the opportunity to escape from crab pot and return to sea to grow. Johnston et al (2011) placed restrictions on commercial fishing activities other than a prohibition on taking berried females and a minimum size limit in Western Australia. In the present study we suggest that the exploitation rate of BSCs including any fishery activities should be less than 0.5 (E < 0.5) which means that natural growth rate of BSCs population is still higher than that of exploited. This condition is found on female BSCs where the exploitation rate was 0.02 (under exploited). Previous studies on portunidae population had been reported that generally its exploitation rate had been overexploited as found on BSCs population in Tiworo Strait (La Sara et al 2014, 2015), Toronipa waters of Konawe (Muchtar 2016; Basri 2016), Bungin Permai waters of South Konawe (Permatahati 2016), and mud crab population in Lasongko Bay (La Sara 2010). The carrying capacity decreasing of the natural resources in the coastal areas may also contribute to the low of BSC population density. This phenomenon showed that some habitats of BSCs such as seagrass bed and mangroves have been experiencing degradation due to heavy exploitation of BSCs, seagrass and mangroves forest. In the previous years exploitation of BSCs around Southeast Sulawesi waters was intensely due to the presence of several “BSC meat processing industries” (Regional Center of Sea Partnership Consortium of Southeast Sulawesi 2006) which urged fishermen to catch more BSCs in order to have high production without sizes selection. La Sara et al (2014, 2015, 2016a) and Muskita et al 2015) suggested that an effort to sustain BSCs population must establish a marine protected area (MPA) for BSCs in order to serve as a shelter, feeding ground, nursery ground and produce seeds to adjacent waters. The MPA is the best example to conserve marine organisms which it will be used for increasing fisheries production (Pet & Mous 2002). Other recommendations which should be taken into account are the fishery can be managed through input controls which regulate fishing methods and gear specifications, seasonal and daily time restrictions, retainable species, minimum size limits and the number of licenses (Johnston et al 2011).

Relative yield per recruit (Y'/R). The relative yield-per-recruit (Y'/R) analysis on BSCs population in the present study showed evidence that growth and recruitment of BSCs population were under heavy pressure due to high exploitation. Exploitation rate (E) increased as shown by the total number of fishing gears (gillnets and crap pots) increase. It causes BSCs population continuously decrease. Economically, such situation indicates a big financial loss (production cost increases but production gained decreases).

The result of yield per recruit (Y'/R) may lead to what management effort should be done. It should be based on several parameters which form yield per recruit equation namely E, c, and M/K where E = F/Z; c = CW_c/CW_∞, and M/K = ratio of natural mortality curvature growth constant. The first two parameters can be monitored through exploitation management, regulation, and legislation (La Sara 2001). In contrary, the last equation can be only understood through reproductive biology knowledge of this species (Gulland 1985; La Sara 2001). It is explained that M/K ratio is constituted by the opportunity of this species completing its potential life prior to reaching natural mortality. A previous study (Haefner 1985) reported that an individual of crab become vulnerable on fishing when a certain age and size of crabs enter the population exploited. It was apparent that the total mortality (Z) of male BSCs was higher than that of females. The main cause of Z male BSCs came from fishing mortality (F), while in contrary Z of females came from natural mortality (M) (Table 3). It was found that population of female BSCs is higher than that of males right now which it may constitute the population number of males and females in the consecutive generations as indicated by Figure 7. Moreover, La Sara (2001) also found similar phenomenon on mud crab (*S. serrata*) that the different Y'/R of both male and female sexes can be explained through several parameters which incorporated in the function of Y'/R namely: (1) the curvature growth constant (K) of males is higher than that of females, (2) CW_∞ of males is smaller than that of females leading to influence CW_c/CW_∞ ratio, and (3) M of males is lower than that of females from the estimated Z.

The data found out in present study apparently indicated that the catch of juvenile and mature BSCs is higher than that of matured BSCs if all stages occupied the same habitat. It may be assured that the opportunity of males to be caught is higher than that of females. It is similar to the analysis of sex ratio which males preponderate over females.

In order to attain Y'/R optimum that the BSCs management in Tiworo Strait should implicate reducing the number of fishermen and their fishing gears used because the exploitation rate (E = 0.668) is already exceeding the normal exploitation rate or it has been experiencing over exploitation (E > 0.5) for males. The same action should be addressed to females although the exploitation rate is not showing over exploitation yet (E = 0.027). If the exploitation rate is increased that it may give effect on decreasing Y'/R (Figure 6 and Figure 7). Therefore, to sustain the BSC population in Tiworo Strait that management action should be directed to its population and habitat.

Conclusions. The trend of BSCs over exploitation in this area could have been happened as shown by several indicators, such as BSCs commonly having small CW of < 9.0 cm, high fishing mortality (F = 2.76) compared to natural mortality (M = 2.14), relatively high exploitation rate (E > 0.5), low catch per unit effort and fishing grounds moving further afield. Recruitment of both sexes attains peak season perhaps in June-July and afterward went down. For management pusposes, efforts should be done particularly all unselective of gillnets and crab pots used by fishermen to be replaced with selective of collapsible crab pots having escape vents of 5.0 cm x 3.5 cm attached in both sides. Other efforts are requesting fishermen not to catch BSCs of < 10 cm CW and females berried eggs have to be returned to the sea in order to have the opportunity to grow and breed. Further studies should be addressed for mapping spatially and temporally fishing and nursery grounds distribution.

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