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Research Article

Population parameters and sex ratio of blue swimming crab (*Portunus pelagicus*) for its population management in Tiworo Strait waters of Southeast Sulawesi, Indonesia

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Keywords

Growth parameters,
Mortalities,
Portunus pelagicus,
Sex ratio,
Growth patterns,
Condition factors

Abstract

The objective of this study was to analyze growth and mortality parameters, growth patterns, and sex ratios of blue swimming crabs (BSCs) for the population management policy in Southeast Sulawesi waters. The samples were collected weekly at Pamandati, Bungin Permai, and Kasipute mini plants from July to September 2023. Growth parameters were relatively similar to other tropical waters, but total mortality was high. The exploitation rate (E) was generally low (E< 0.5), except in Pamandati (E = 0.58). BSCs exhibited negative allometric growth (b<3), with carapace width (CW) contributing >55% to weight (W). Poor environmental conditions of BSC habitat were indicated by a negative condition factor. Efforts to maintain the sustainability of BSCs population while providing high economic and social value suggest that BSCs exploitation can still be increased until reaching E=0.5, but BSC females should outnumber males to support reproduction. Juveniles (<10 cm CW) and spawning females should be protected, and mangrove habitats preserved. This study supports and strengthens sustainable BSC management in Indonesia.

Article info

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Introduction

Blue swimming crab (BSC) is one of the important fisheries commodities (Balitbangkan and Asosiasi Pengelola Rajungan Indonesia [APRI]), 2016), alongside large pelagic fish, small pelagic fish, demersal fish, reef-associated fish, mud crab, lobster, penaeid shrimp, and squid, regulated according to the Fisheries Management Area (FMA) of the Republic of Indonesia (The Minister of Marine Affairs and Fisheries Regulation No. 22 of 2021). The BSC fishing grounds in Indonesia are distributed along the coastal areas, starting from the western tip of Sumatera Island, the Java Sea waters, the southern and western parts of South Sulawesi and Southeast Sulawesi waters, extending to the eastern part of Papua waters (Sumiono, 1997; La Sara *et al*., 2016a; Astuti *et al*., 2020a). The largest production of BSCs comes from the northern waters of Java Island, followed by East Lampung waters and Southeast Sulawesi waters. The BSC fishing grounds occur across estuaries, intertidal zone, marine embayments and coastal areas (Johnston *et al*., 2019) to a depth of approximately 30 m (La Sara *et al*., 2017). The Tiworo Strait waters constitute the main BSC fishing ground in Southeast Sulawesi (La Sara *et al*., 2016a; 2017; Permatahati *et al*., 2020; Cardin *et al*., 2023).

The BSC fishery is a crucial resource for small-scale fisheries. Juveniles are commonly found in the intertidal zone near mangrove areas and are captured using collapsible crab traps. At the same time, the individuals with a carapace width (CW) of >8 cm are typically caught in a water depth of >20 m using gillnets (La Sara *et al*., 2017). Generally, the intensity of BSC capture is concentrated in the intertidal zone to a water depth of 6 – 8 m using collapsible crab traps. Both types of fishing gear used are considered unselective fishing gear (La Sara *et al*., 2016a; Permatahati *et al*., 2020). Due to the concentrated capture in the intertidal zone, where BSC are mostly juveniles and only a few reach the size of 8 cm, there is concern that the BSCs population is at risk of decline.

Over the past decade, there have been indications that the BSC population in the Southeast Sulawesi waters and other areas has declined as it fulfills the criteria for overexploitation due to domestic and overseas markets in the USA continuously increasing (Balitbangkan and Asosiasi Pengelola Rajungan Indonesia [APRI]), 2016). These criteria include a CW less than 6 cm, diminishing fishing grounds, and a decreasing Catch per Unit Effort (CPUE). It had been reported that BSC population experienced a drastic decline from 2014 to 2017, and in some places, they were no longer found (La Sara *et al*., 2016a; 2017). This situation has to be overcome using management measures such as ban capture BSC under a minimum legal size (MLS) of 10 cm carapace width and berried females. Since the last five years, fishers have almost totally ceased crab fishing activities due to the price of BSC meats being very low either in domestic or overseas markets. As a result, data on BSCs has not been properly recorded. It was hoped that during this period, there would be a recovery of the BSC population. Furthermore, the data from this study can be used to formulate a quota-based fishing management policy for BSCs in the Southeast Sulawesi waters under the Government Regulation No. 11 of 2023. The regulations control the total allowable catch (TAC) of BSCs based on the potential population (Maximum Sustainable Yield/MSY) and exploitation levels (E) in each fishing ground or FMA. The issue with quota-based fishing management of the BSC population is that the potential, capture efforts, and biology data have not been adequately recorded to date, while its population exploitation had been intensively exploited for decades without CW size selection and ban berried females (Balitbangkan KKP and APRI., 2016; La Sara *et al*., 2019; Cardin *et al*., 2023).

The study on some population parameters and reproductive biology of BSCs has not been conducted since the early 2020s. Meanwhile, the management of quota-based fishing for BSCs in each fishing ground or FMA must be implemented in January 2025 (Government Regulation No. 11 of 2023 and Minister of Marine Affairs and Fisheries Regulation No. 28 of 2023). Previous studies on BSC had been conducted in Southeast Sulawesi waters such as reproductive biology (La Sara *et al*., 2016a), effort in harvest control (La Sara *et al*., 2016b), stock status (La Sara *et al*., 2019; Permatahati *et al*., 2020), sex ratio and growth performance (Astuti *et al*., 2020a), size structure distribution (Astuti *et al*., 2020b), and population parameters (Cardin *et al*., 2023)

This study approach, which includes population growth parameters, mortality, and reproductive biology, is crucial and should be carried out to assist in formulating population management strategies. The objective of this study is to analyze growth parameters ($CW\infty$ and K), mortality parameters, growth patterns, and sex ratios of BSCs.

Materials and methods

Location and sampling procedure

The BSCs were caught by fishers in the BSC fishing grounds of Pamandati, Bungin Permai, and Kasipute in the Tiworo Strait, Southeast Sulawesi, Indonesia (Fig. 1). These BSCs were then directly sold at the respective mini-plant (MP) of BSCs in Pamandati, Bungin Permai, and Kasipute. These MPs can process BSCs from fishers ranging from 100 to 300 kg per day. The samples of crabs were collected weekly at each of those MPs from July to September 2023. Each sample was sexed (male and female) and measured their CW to the base of the last anterolateral spines using a caliper with an accuracy of 0.1 mm (Fig. 2). Additionally, their body weight (W) was measured using an electronic balance with an accuracy of 1 g.

Data analysis

The catch data for each sex from each MP were analyzed based on CW, growth parameters ($CW\infty$, K), total mortality (Z), fishing mortality (F), and natural mortality (M). Size compositions were tabulated in terms of CW frequency distribution, while the $CW\infty$, K from all MP data were analyzed using the von Bertalanffy growth function as follows:

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

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

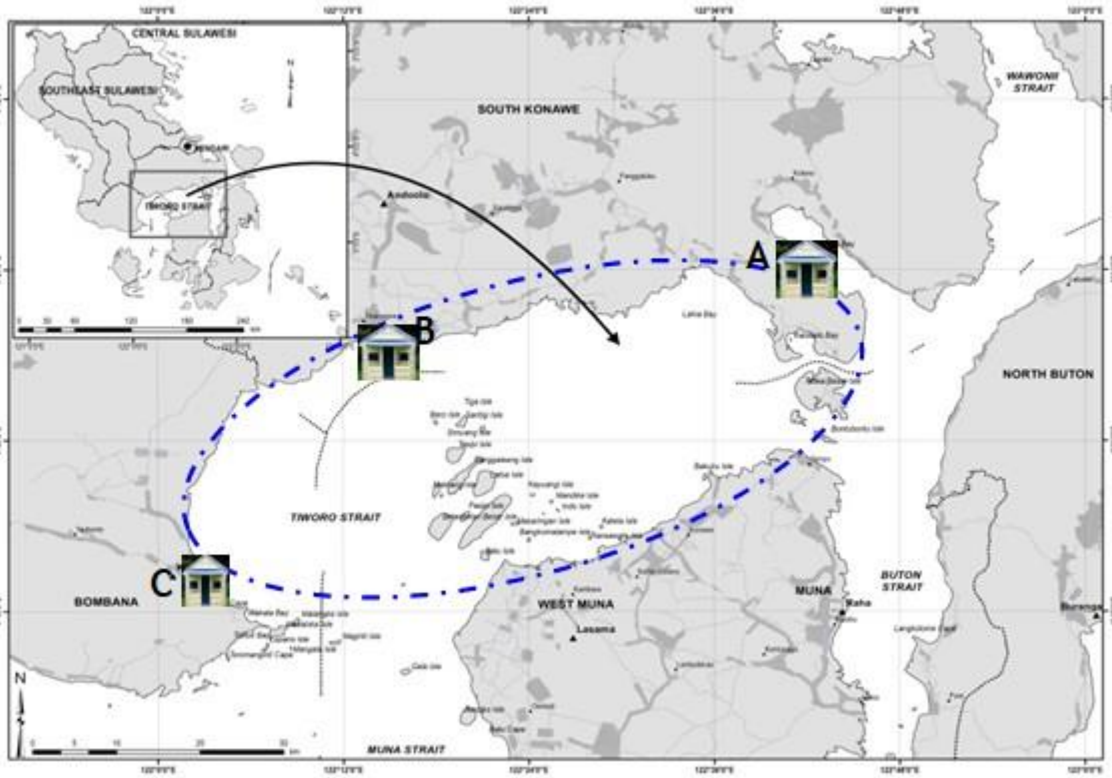

Figure 1: Map of BSC fishing ground in Tiworo Strait waters (blue dashed circle) and BSC MP in Pamandati (A), Bungin Permai (B), and Kasipute (C) of Southeast Sulawesi, Indonesia.

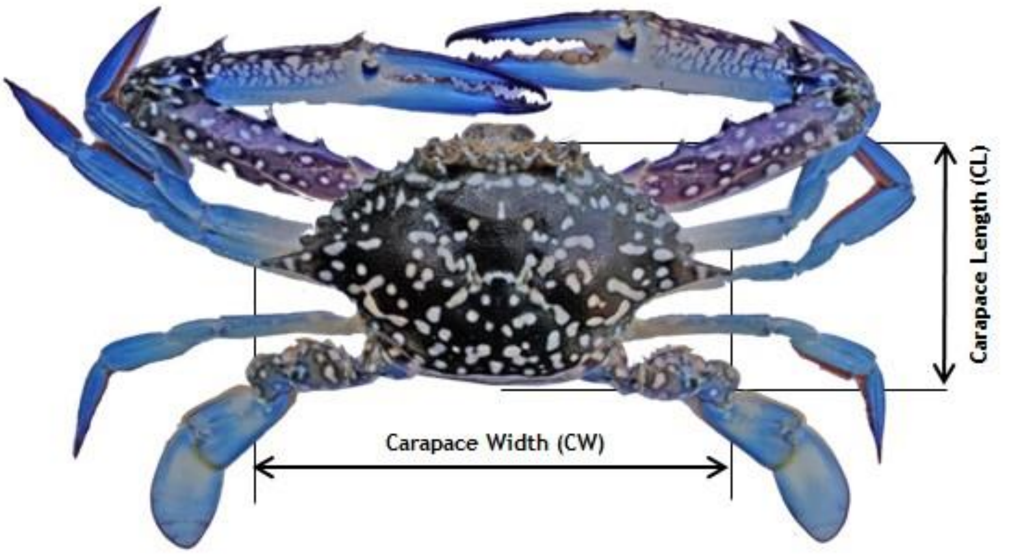

Figure 2: Measurement of various morphometric aspects of *Portunus pelagicus*.

The Z was estimated based on the availability of CW frequency data. This was achieved by summing up all CW frequency data and then converting it into a catch curve method, Z/K (assuming a steady-state population) (Sparre and Venema, 1998) utilizing the relationship provided by Pauly (1980). Pauly's equation takes the form of a linear regression where the slope (b with sign changed) represents the Z. To convert the CW frequency into a catch curve, CW∞ and K values derived from the ELEFAN I method, as incorporated in the FiSAT II program (Gayanilo *et al*., 1996), were used with t_0=0. The catch curve was plotted with Log_e (N/Δt) as the ordinate and the relative age (t') as the abscissa. This facilitates the selection of points to be included in the computation of Z. The M is calculated as Z–F (where F is the fishing mortality).

The regression coefficient (b) in the equation $W=aCW^b$ illustrates the growth pattern of BSC, indicating the relationship between W and CW. This regression equation can be linearized as LogW=Loga+b*LogCW, where W=body weight, CW=carapace width, a=intercept on CW or the initial coefficient of growth, and b=slope or growth coefficient. Some studies suggest that BSC exhibits an isometric growth pattern (b=3), indicating that the increase in W is proportionally followed by an increase in CW. However, if BSC exhibits an allometric growth pattern, they may be classified into positive allometric growth (b>3) or negative allometric growth (b<3) (Astuti *et al*., 2020b; Waiho *et al*., 2021; Maria *et al*., 2024).

If the growth pattern is isometric, the health index of BSC, expressed as the condition factor (CF), was analyzed using "condition factor" CF = $[10^5W/CW^3]$, while allometric growth pattern ($b \neq 3$) that CF = $[W]/[a*CW^b]$ (Omar *et al*., 2020; Paramo *et al*., 2024), where W is the average body weight of BSC (g), CW is the average carapace width BSC (cm), a=the intercept, and b=growth coefficient from the W-CW relationship (Noori *et al*., 2015; La Sara *et al*., 2016a; Astuti *et al*., 2020a, 2022; Paramo *et al*., 2024).

The sex ratio of male and female BSCs data taken from each MP was analyzed using the formula:

$$SR = \frac{\sum male}{\sum female}$$

The significance of BSC sex ratio was tested using Chi-square (α=0.05) (Sudjana, 1989) using Microsoft Excel version 2018, namely:

$$\chi^2 = \sum_{k=0}^{n} \frac{(O - E)^2}{E}$$

where: χ^2=Chi-square, O=male and female BSC frequency observed, E=male and female BSC frequency expected.

Results

The growth parameters of CW∞ and K values for male and female BSCs across all MPs were relatively similar, with male growth parameters generally being higher than females, except for BSC CW∞ in MP Kasipute. The male CW∞ parameter in MP Bungin Permai was higher than in other MPs, while the female CW∞ parameter in MP Kasipute was higher than in other MPs. Male K values from all MPs were consistently higher than females. This analysis also included an examination of Z, M, and F values of BSC. The M values of male BSCs from all MPs were higher than those of female BSCs. Similarly, F values were generally higher for males, except in cases where the male F value in MP Kasipute was lower than the female F value. Overall, F values for both sexes were higher than M values, except for females in MP Pamandati and males in MP Kasipute. This led to an under-exploitation rate (E<0.5) and moderate exploitation (E=0.58) (Table 1).

Table 1: Parameters of growth, mortality, and exploitation rate of BSC (*Portunus pelagicus*) collected from MP of Pamandati, Bungin Permai, and Kasipute of Southeast Sulawesi, Indonesia.

No.	Fish Landing Site	Sex	Growth Parameter		Mortality Parameter			Exploitation Rate
			CW∞	K	M	F	Z	(E)
1.	MP Pamandati	Male	16.64	1.6	2.86	3.99	6.85	0.58
		Female	14.80	1.3	2.58	1.06	3.64	0.29
2.	MP Bungin Permai	Male	16.91	1.8	3.07	9.31	12.38	0.75
		Female	15.12	1.5	2.82	3.25	6.07	0.54
3.	MP Kasipute	Male	12.76	1.8	3.33	2.45	5.78	0.42
		Female	16.97	1.6	2.84	4.25	7.09	0.60

The parameters a and b estimated for the W – CW relationship of both male and female BSCs are presented in Table 2. The growth patterns of BSCs in all these MPs were negatively allometric (b<3). However, the W – CW relationships for both sexes at all MPs (fish landing sites) had a strong correlation coefficient (r>0.90), with MP Pamandati showing the highest values (r=0.9520 for males and r=0.9245 for females) compared to the other MPs. The CF values for BSCs at all MPs were negative for both sexes (Table 2), and the CF values of BSCs at MP Pamandati (CF= -1.5591 for males and CF= -1.5296 for females) were lower than those of the other MPs.

Table 2: Regression parameters and condition factors of BSC (*Portunus pelagicus*) collected from MP Pamandati, Bungin Permai, and Kasipute of Southeast Sulawesi, Indonesia.

No.	Fish Landing Site	Sex	Regression Parameter		r	n	CF
			a	b			
1.	MP Pamandati	Male	-1.1219	2.9079	0.9520	779	-1.5591
		Female	-1.1740	2.9818	0.9245	820	-15296
2.	MP Bungin Permai	Male	-1.0853	2.8956	0.9074	724	-1.6408
		Female	-1.0103	2.7963	0.9154	871	-1.7323
3.	MP Kasipute	Male	-0.8348	2.6419	0.9013	402	-2.2648
		Female	-1.1124	2.8870	0.9389	408	-1.6603

The sex ratio of male and female BSCs caught in Tiworo Strait waters and landed in MP Pamandati, Bungin Permai, and Kasipute indicated that the number of females exceeded the number of males (female>male) although was not significant different (Table 3).

Table 3: Sex ratio of BSC (*Portunus pelagicus*) collected from MP Pamandati, Bungin Permai, and Kasipute of Southeast Sulawesi, Indonesia.

No.	Fish Landing Site	Sex Ratio	
		Male	Female
1.	MP Pamandati	1	1.05^{ns}
2.	MP Bungin Permai	1	1.20^{ns}
3.	MP Kasipute	1	1.01^{ns}

ns = not significantly different

Discussions

The population growth of BSCs is largely determined by food availability, aside from factors such as water temperature, inter-specific and intra-specific competition, and other environmental quality. Population growth parameters for both males and females of BSC are described by CW∞ and K, which are analyzed using the von Bertalanffy growth equation. The analysis of CW∞ and K parameters of both male and female BSC obtained from the three MPs showed relatively similar values, except for MP Bungin Permai (Table 1). Generally, the growth rate of males is higher than females because to energy consumed is used for growth itself dan maintenance, while the energy consumed for females for growth, maintenance, and sexual reproduction. This fact also was found in this study, except BSC in MP Kasipute although K value of males was higher than females.

The CW∞ values in this study are relatively small compared to those obtained from other locations, although the K values are relatively larger in this study compared to other locations such as in Bantayan waters of Philippines, Peel-Harvey Estuary of Australia, Mediterranean coast, and Red Sea of Egypt, and Southern Persian Gulf of United Arab Emirates (Table 4). It has been reported that CW∞ values of 16.8 cm and K values of 1.2/year (male) and CW∞ of 17.78 cm and K of 1.1/year (female) (Kamrani *et al*., 2010), while La Sara *et al*. (2017) reported CW∞ values of 16.09 cm and K of 1.3/year (male) and 16.93 cm and K of 0.55/year (female). The K values obtained in this study are also larger than those reported in these two studies. Other studies conducted in the waters northern part of Java island showed a relatively higher of CW∞ (17.75 cm), but a relatively lower K (1.10/year) (Ernawati *et al*., 2017). Generally, larger CW∞ values are accompanied by smaller K values. Morgan and Pauly (1987) also observed a similar pattern (Table 4).

The differences in population growth parameter values, including the variations compared to the results of this study, can be attributed to ecological and environmental conditions at the sampling locations, particularly influenced by salinity, temperature, and the bottom substrate (El-Kasheif *et al*., 2021). Tidal movements also play a role in determining the dynamics of BSCs in certain locations, which in turn ultimately affects the sample sizes (La Sara *et al*., 2016a; 2016b; 2017). The number of samples analyzed, the methods used, and the season of sample collection can impact the sample size obtained, potentially influencing the results of the BSC population growth parameter analysis. Sparre and Venema (1998) explained that the growth rate differs between population stock and other various fisheries.

The values of BSC mortality parameters in this study are relatively high (Table 1) which are contributed mostly by fishing mortality (F>M), except BSC females in MP Pamandati and BSC males in MP Kasipute lead to low exploitation rate or under exploitation (E<0.5). Meanwhile, aside from all that, the natural mortality contribution is lower than those of fishing mortality (M<F) leading to a moderate exploitation rate (E=0.54 – 0,75).

Table 4: Population growth parameters of *Portunus pelagicus* around tropical waters in Asia and Australia in previous studies.

No.	Location	Sex	Growth parameter CW∞ (cm)	Growth parameter K/year	Source
1.	Bantayan waters, Philippines	Male	22.5	0.98	Inglesh (1996)
		Female	22.5	0.70	
2.	Mangalore, Malpe and Karwar waters, India	Male	21.1	1.14	Sukumaran and Neelakantan (1997)
		Female	20.4	0.97	
3.	Peel-Harvey Estuary, Australia	Female	20.4	0.97	de Lestang *et al*. (2003)
		Combined (1980-1981)	15.57	3.0	
		Combined (1995-1998)	12.89	1.3	
4.	Queensland, Australia	Male	17.5	1.62	Sumpton *et al*. (2003)
		Female	17.7	1.61	
5.	Bardawil Lagoon, Egypt	Combined	8.38	2.04	Mehanna and El-Aiatt (2011)
6.	Pakistani waters (Northern Arabian Sea), Pakistan	Combined	17.85	1.7	Afzaal *et al*. (2018)
7.	Kota Baru waters, Indonesia	Male	17.92	1.36	Tirtadanu and Suman (2017)
		Female	18.36	1.11	
8.	Mediterranean coast, Egypt	Combined	18.3	0.27	El-Far *et al*. (2018)
9.	Jakarta Bay, Indonesia	Combined	15.7	1.0	Panggabean *et al*. (2018)
10.	Kwandang waters, Indonesia	Male	17.4	1.24	Tirtadanu and Chodrijah (2019)
		Female	18.0	0.96	
11.	Red Sea, Egypt	Combined	21.19	0.41	El-Kasheif *et al*. (2021)
13.	Southern Persian Gulf, United Arab Emirates	Combined	18.27	0.46	Farrag *et al*. (2022)

This fact indicates that even though the price of BSCs during this period is low, fishers continue to catch and sell them to MPs to meet their family's needs. During this period, the selling price of BSC was lower than the total catching cost. Consequently, the fishers's dependence on BSC resources in the Tiworo Strait waters is very high. However, it is not yet known whether this low fishing mortality in the waters of Pamandati for females and Kasipute for males leading to under-exploitation (E<0.5) is due to fishers refraining from catching which was affected by the price of BSC meats being very low, both domestically and in the United States as the main export destination in the last past five years or it is caused by BSC habitat degradation, resulting in higher natural mortality (M>F). The second factor can be explained by the intense pressure on the BSC habitat in these waters due to mangrove deforestation for community needs and conversion for ports, settlements, roads, and other purposes. The mangrove forests in these waters are crucial habitats for BSC, especially in the juvenile stage (La Sara *et al*., 2016a; 2017). King (1995) stated that generally, M values for both sexes are higher due to predation. The situation is different in the waters of Bungin Permai - a region separated from the mainland - where fishers intensively catch crabs because it is their primary source of income. This factor leads to a higher fishing mortality rate for BSCs compared to natural mortality (F>M).

The natural mortality parameter values obtained in this study are higher compared to those reported by La Sara *et al*. (2017) in the same water locations, except in the waters of Bungin Permai. The aforementioned study showed a variation exploitation rate (E) of male BSCs and female BSCs in different locations (Table 5). The values of mortality parameters in other waters also show variation, but they are relatively similar to the findings in this study, falling into the category of under-exploitation (E<0.5). However, in Bungin Permai, the exploitation rate (E) was moderate (0.5<E<1.0), indicating that the value of F is relatively greater than the value of M. In contrast, under-exploitation indicates that the value of F is relatively smaller than the value of M (Table 5). According to King (1995), the causes of natural mortality include age-related factors, while La Sara (2001) extensively discussed natural mortality in *S. serrata* attributing it to predations, death during molting due to predation by other individuals, parasites, and drastic changes in environmental factors in the water (Table 5).

Table 5: Mortality parameters of *Portunus pelagicus* around tropical waters in Asia and Australia in previous studies.

No.	Location	Sex	M	F	Z	E	Sources
1.	Karwar, India	Male	-	-	4.29	-	Sukumaran and Neelakantan (1996)
		Female	-	-	3.55	-	
2.	Mengalore, India	Male	-	-	6.85	-	Sukumaran and Neelakantan (1996)
		Female	-	-	5.31	-	
3.	Oman coastal waters	Combined	3.2	4.7	7.9	0.59	Mehanna *et al*. (2013)
4.	Tiworo Strait of Southeast Sulawesi, Indonesia	Male	1.37	2.74	4.11	0.67	La Sara *et al*. (2017)
		Female	0.77	0.02	0.79	0.30	
5.	Kwandang waters, Indonesia	Male	1.28	0.72	2	0.36	Tirtadanu and Chodrijah (2019)
		Female	1.07	0.86	1.93	0.45	
6.	Red Sea, Egypt	Combined	1.285	1.644	2.929	0.56	El-Kasheif *et al*. (2021)
7.	Southern Persian Gulf, United Arab Emirates	Combined	0.7	0.83	1.53	0.54	Farrag *et al*. (2022)

The growth patterns of BSC, as indicated by b in the regression equation of LogW=Loga+b*Log CW, imply that W is a function of CW (Hajjej *et al*., 2016, Afzaal *et al*., 2018). This approach is suitable for evaluating crustacean populations (Gokce *et al*., 2006; Sangun *et al*., 2009). All growth patterns of BSCs obtained from the three MPs exhibited negative allometric growth (b<3), indicating that the increase in W with CW is not proportional (Table 2). However, the r values ranging from 0.9013 to 0.9520 suggest that CW increment correlation is 90.13% to 95.20% with W increment. Several factors influence the growth patterns of BSC, including life stages, sex, gonad maturity stages, individual health, food availability, seasonal effects (temporal), and the type of habitat (spatial).

Knowledge about the growth patterns derived from the relationship between W and CW of BSCs is crucial in fisheries biology and can be applied in BSC fisheries management (Astuti *et al*., 2020a). This information is valuable for stock assessment (Gokce *et al*., 2006; Sangun *et al*., 2009) and is essential for understanding the exploitation of BSCs (Josileen, 2011). In general, crustacean growth is highly dependent on individual life stages and changes in both W and CW sizes during moulting increments. La Sara (2001) investigated moulting in *S. serrata*, demonstrating that CW and W sizes increase by a certain percentage from their original sizes. It was shown that growth is a function of the increment of W and moulting frequency (Hancock and Edwards, 1967).

The parameter values, including the condition factor (CF) values, can provide insights into the environmental conditions of the water for BSCs. The condition factor, commonly known as the Fulton condition factor, serves as an index for comprehending the life cycle and acts as an indicator of the BSC habitat. A higher W at a given CW implies a better physiological condition of the BSC. The CF values of BSCs taken from all MPs in this study were negative (Table 2). The CF of *P. segnis* in the Gulf of Gabes, Tunisia, ranged from 0.00691 to 0.34767 (with a mean of 0.0582) (Hajjej *et al*., 2016). The authors noted that the CF decreased with an increase in crab size. Another study on BSC from the Java Sea, Indonesia reported different CF values for males (5.04–8.88) and females (4.22–11.70) (Rohmayani *et al*., 2018). It appears that the variation in CF values can be attributed to differences in W and CW sizes, species, sex, sampling locations, water temperature, and salinity. Gayanilo *et al*. (1996) explained that CF may be affected by sex, maturity stages, stomach contents, while Hajjej *et al*. (2016) mentioned environmental factors, gonad development, feeding and growth rates, and degree of parasitism. Tesch (1971) pointed out that CFs are strongly influenced by both biotic and abiotic environmental factors. Le Cren (1951) previously explained that CF is a quantitative parameter representing the condition of the fish, extremely important in fisheries biology (Casselman *et al*., 1987). Over a long period of study on fish, it has been observed that CF helps detect contamination or any situation causing long-term physiological stress in fish populations (Swingle and Shell, 1971).

The samples of BSCs taken from all MPs totaled 1599 individuals, consisting of 779 males and 820 females in MP Pamandati, 1595 individuals, consisting of 724 males and 871 females in MP Bungin Permai, and 810 individuals, consisting of 402 males and 408 females in MP Kasipute. The ratio of males to females at each MP was 1:1.05, 1:1.20, and 1:1.01, respectively (Table 3). This sex ratio in this study is quite similar to the study results conducted in Tiworo Strait of Southeast Sulawesi in 2016, with M:F ratios of 1:1.032 (La Sara *et al*., 2016a), in Khuzestan coasts of Iran (Jazayeri *et al*., 2011), in the Java Sea of Indonesia (Rohmayani *et al*., 2018), and in Veraval of Gujarat, India (Dash *et al*., 2013). The latest study conducted in Tiworo Strait showed that females outnumbered males (Astuti *et al*., 2020a), but it contrasts with the results of a study conducted off southern Australia, where males preponderated over females (Xiao and Kumar, 2004), in the Persian Gulf Coasts of Iran, with an M:F ratio of 1:0.88

(Hosseini *et al*., 2012), and in the southern Persian Gulf of the United Arab Emirates, with an M:F ratio of 1:0.91 (Farrag *et al*., 2022).

The disparity in sex ratio among BSCs may be attributed to various factors such as different reproductive activities between males and females (Kumar *et al*., 2000), natural and fishing mortality of each sex (La Sara, 2001), faster growth rate of males compared to females, occupation of different habitats by each life stage of BSCs, and migration behavior from juvenile to pre-mature and mature stages. Additionally, food availability in the habitat of BSCs, the method of sampling, and fishing gear used can influence the sex composition of caught BSCs, particularly during the spawning season when females may reduce their appetite (Kumar *et al*., 2000). As Portunids attain maturity, females migrate to sea water to spawn offshore (saline water) (La Sara, 2001, de Lestang *et al*., 2003, Kamrani *et al*., 2010, Astuti *et al*., 2020a), leading to a smaller number of females in estuarine waters compared to males (La Sara, 2001). Meanwhile, juvenile BSCs continue to inhabit adjacent mangroves with muddy substrates (La Sara *et al*., 2016a; 2016c). La Sara *et al*. (2016a) mentioned that these phenomena partly account for the low percentage of female BSCs in estuarine waters. However, this explanation differs from a study conducted off southern Australia, where the sex ratio of males increased with water depth from January to September and decreased with water depth from October to December (Xiao and Kumar, 2004).

The findings of this study, indicating growth parameters should be maintained through reducing fishing efforts and protecting mangroves as habitat of mainly juvenile BSCs. Besides, the environmental condition BSCs needs to be preserved in order to keep the growth of BSCs in good condition. It is crucial to maintain females outnumber males (F>M) for sustaining the population of BSCs. Allowing female BSCs with CW<10 cm and berried females (carrying eggs) to grow until they release their eggs for hatching, followed by larval development into megalopa, juvenile, and eventually reaching the adult stage, is essential for the continuity of the population of BSCs. Mature BSCs that have reached the adult stage are expected to engage in mating again until they are ready to spawn. Such efforts represent an appropriate harvest strategy in the management of BSC resources, as regulated by the Minister of Marine Affairs and Fisheries Regulation of the Republic of Indonesia No. 16 of 2022 on the Management of Lobster (*Panulirus* sp.), Crab (*Scylla* sp.), and Blue Swimming Crab (*Portunus* sp.) in Indonesian waters, which prohibits the capture of BSCs with CW<10 cm and berried females.

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Conflicts of interest

The authors have no conflicts of interest to declare.

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