



Temporal sex ratio, growth patterns and condition factor of the blue swimming crab (*Portunus pelagicus*) in Northern of Tiworo Strait waters, Southeast Sulawesi, Indonesia

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ABSTRACT

Blue swimming crabs *Portunus pelagicus* occupied Tiworo Strait waters has been experiencing heavy pressure due to high exploitation and damaging its habitat caused by conversion to be a port or jetty particularly in the intertidal and subtidal zones closed to mangrove areas and river mouth. Those zones constitute main habitats of BSCs. The study aimed to analyze temporal sex ratio (SR), growth patterns and condition factor (CF) of BSCs in Tiworo Strait waters which was conducted in June–December 2018. The BSC samples were taken monthly using collapsible pot. Each sample taken was identified its sex, measured its CW and weighed its BW. Monthly SR of male and female was counted, while BW–CW relationship was analyzed using a simple linear regression. Growth patterns and CF were derived and analyzed from BW–CW regression. The results of study showed that monthly BSC SR of male and female showed females preponderated over males, except in November. The growth pattern of male and female was negative allometric ($b > 3$). Data of BSCs CF were mostly influenced by growth coefficient (b), namely the higher b the lower CF. This condition is frequent happening in BSC population dominated by juvenile and mature stages. This study showed most BSCs found in this location were juvenile which indicated as their nursery ground in the intertidal zone dominated by sand substrate closed to mangrove forest.

Introduction

Blue swimming crabs (BSC), *Portunus pelagicus* “*sensu stricto*” (refers to the present revised concept of this species), which previously was known as *P. pelagicus* “*sensu lato*” (previous concept of this species as it considered to date) (Lai *et al.*, 2010) constitute an organism inhabiting sea water which have wide range distribution covering western Indo-Pacific from Japan waters, across Southeast (Philippines, Malaysia, Indonesia) and East Asia (Lai *et al.*, 2010) up to eastern Australia from Cape Naturaliste in Western Australia north to the Northern Territory, across Queensland, and down the east coast to the New South Wales – Victorian border (Johnston *et al.*, 2012). This organism is found also in Fiji Island waters, Red Sea and East Africa (Williams, 1982; Edgar, 1990; Potter and de Lestang, 2000; Johnston *et al.*, 2011) and in the

warmer waters of the South Australian gulfs (Kailola *et al.*, 1993). In Indonesia waters, this organism is found almost in the entire of islands from western Sumatera tip, northern Java waters, South Sulawesi waters and Southeast Sulawesi up to eastern Papua waters (La Sara *et al.*, 2016a). In Southeast Sulawesi waters, this organism occupies all coastal zones, however, in the present this organism is dominant caught in Tiworo Strait waters and Lasongko Bay (Muskita *et al.*, 2015; La Sara *et al.*, 2017).

This organism is included in the family of Portunidae which has premium price due to huge number of domestic and international people consumed as prestigious main stuff. This reason pushes fishermen catch it intensively in coastal waters at the water depth of 1 – 5 m up to sea water with water depth of > 30 m (Zairion *et al.*, 2014; La Sara *et*

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al., 2016a; 2017). Edgar (1990) explained that this organism prefer habitat in the coastal waters with muddy substrate or grown by seagrass and alga bed at the water depth of around 50 m. In Southeast Sulawesi waters, BSC juvenile and pre-adult habitats have dominated sand substrate mix with small percentage of mud at the intertidal zone closed to mangrove forest, river mouth, or waters grown by seagrass (La Sara et al., 2016a; 2017). Those habitats are easily reached by fishermen lead to easy and intensive catch this organism all year rounds (Basri et al., 2017).

Initially this organism was caught by fishermen are only to fulfill their daily household consumption needed and some distributed at local market. Local people knew that this organism and other Portunidae is a source of protein in the main food consumed, but when demand of international people of US, Europe, and other Asian countries such as Japan, Singapore with premium price that it was caught unrestrained and intensive using unselective fishing gears of collapsible pot (cubic and rounded shape) and bottom gillnet. There was little number of fishermen still used bottom trawl and fish rod. Several fishing ground of this organism had shown over exploitation as indicated by small carapace width (< 7 cm) and catch-per-unit-effort (CPUE) of 2 – 3 kg/trip (La Sara et al., 2016b; Muchtar et al., 2017).

There were several previous studies had been done on this organism around Southeast Sulawesi waters such as catch diversity by fishermen, size composition, habitat and abundance, reproductive biology (La Sara et al., 2016a; Basri et al., 2017; Permatahati et al., 2019), population parameter (La Sara et al., 2017; Muchtar et al., 2017), and fishing gear selectivity (La Sara et al., 2016c), but study on BSC population experiencing heavy and intensive exploitation has not been investigated yet. It is assumed that impact of those exploitations could happen in its biological characteristics. The present study investigated temporal sex ratio (SR), growth patterns and condition factor under the recent of those BSC population condition. The results of study will provide some biological and growth information which are important to be used for the better and sustainability BSCs fishery management.

Materials and Methods

Sampling site

Tiworo Strait waters constitutes one among BSC fishing grounds which is exploited very intensive in Southeast Sulawesi waters. Sampling location of BSCs was chosen in Tinanggea waters of South Konawe (Figure 1) due to all sizes of BSC (juvenile, pre-adult

and adult) were found in this location. Data collection of BSCs were carried out in June – December 2018.

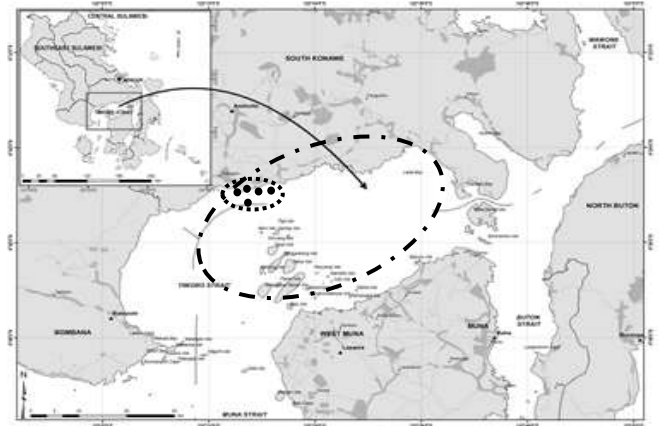


Figure 1. Map of sampling location of BSC (full black circle) in Tiworo Strait waters of Southeast Sulawesi (black dash line)

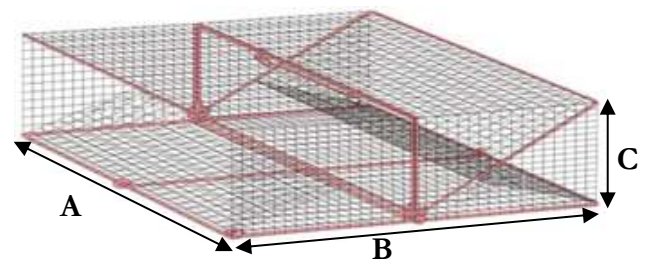


Figure 2. Collapsible trap used for BSC sampling in Tiworo Strait of Southeast Sulawesi (54 cm length (A), 36 cm width (B), and 19 cm height (C)) (La Sara et al., 2016c)

Sampling procedures

The BSCs sampling were taken monthly using collapsible pot of cubic shape (54 cm length, 36 cm width, and 19 cm height) which its frame made from steel covered by net of $\pm 0,5$ cm mesh size (Figure 2) as many 150 unit deployed every sampling. Each collapsible pot was tied in a nylon polypropylene main rope using much smaller nylon rope. Distance between collapsible pots in this main rope was ± 10 m. Each collapsible pot was put fish bait fresh hung in the middle part. All collapsible pots arranged in the main rope were deployed in each sampling location during flood tide and then pull it out during ebb tide.

Each BSC caught was identified its sex according to abdomen morphological characteristics. Male BSC has V-shape abdomen (V-shaped), while female one has broad shape abdomen or rounded shape (Van Engel, 1958; Ingles and Braum, 1989; Potter and de Lestang, 2000). Each individual of sex was measured its carapace width (CW) using a Vernier calliper to the nearest 0.1 mm (measured as the distance between the

tips of the posteriormost lateral carapace spines) and weighed its body weight (BW) using an electronic balance to the nearest 1 g, and then each sex was counted its number (La Sara et al., 2016a; 2017).

Data analysis

BSC SR

The number of male and female BSCs taken monthly from each location was analyzed its SR using formula:

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

Significant of BSC SR was tested using Chi-square ($\alpha = 0.05$) (Sudjana, 1989), namely:

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

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

Growth pattern and condition factor (CF)

Growth pattern of BSCs was shown by a coefficient of growth (b) of the body weight (BW) – carapace width (CW) relationship which was analyzed using an growth equation of $BW = aCW^b$ ($\log BW = \log a + b \log CW$); where BW = body weight; CW = carapace width; a = intercept on CW or initial coefficient of growth; b = slope or growth coefficient. Generally BSCs follow an isometric growth pattern (b = 3) which means increasing BW is proportionally followed by increasing CW. When those have an allometric growth pattern that those may be classified into positive allometric growth pattern (b > 3) which means increment BW is faster than its CW, and negative allometric growth pattern (b < 3) which means increment BW is slower than its CW. Due to male and female BSCs growth pattern in the study location followed negative allometric growth pattern

that healthy index of BSCs was analyzed using “relative condition factor” (CF) estimated following equation of $CF = [BW]/[aCW^b]$, where BW = average body weight (g), CW = average carapace width (mm), a and b = in respective intercept and growth increment coefficient from BW – CW relationship (Noori et al., 2015).

Results

Sex ratio

Monthly BSCs SR of male and female caught in June – December in the sampling sites of Tiworo Strait showed female number generally preponderated over male number (female > male), except its number in September was equal (male = female) and November where male preponderated over female (male > female) (Table 1). Chi-square test ($\alpha = 0.05$) showed that male and female BSC SR were significant different ($\alpha < 0.05$), except in September was not significant different ($\alpha > 0.05$).

Growth pattern and condition factor

Information found from BW – CW relationship of several organisms and particularly BSCs have big significant into fisheries biology and have several application into several subject of BSC fisheries management. The BW – CW relationship in the present study was analyzed using samples of male and female BSC taken monthly. The results of analysis showed strong correlation coefficient ($r > 0.75$), except male ($r = 0.5632$) and female ($r = 0.5154$) in November (Figure 3). Figure 3 showed that monthly male and female BSCs growth pattern during the course of study, which were negative allometric (b < 3) (Table 2). It is why healthy index of those BSCs was counted following “relative condition factor” (CF). Data of that BSCs BW – CW relationship were derived to find out index of BSC CF (Table 3).

Table 1. Temporal of male and female BSC Sex Ratio in Tiworo Strait waters, Southeast Sulawesi.

Sex Ratio	June	July	August	September	October	November	December
Male : Female	1 : 1.147*	1 : 1.415*	1 : 1.369*	1 : 1 ^{ns}	1 : 1.703*	1.205 : 1*	1 : 2.667*

* = significant different at $p < 0.05$; ns = no significant different at $p < 0.05$

Table 2. Monthly growth pattern of male and female BSC in Tiworo Strait waters, Southeast Sulawesi.

Sex	Growth Pattern						
	June	July	August	September	October	November	December
Male	negative allometric	negative allometric	negative allometric	negative allometric	negative allometric	negative allometric	negative allometric
Female	negative allometric	negative allometric	negative allometric	negative allometric	negative allometric	negative allometric	negative allometric

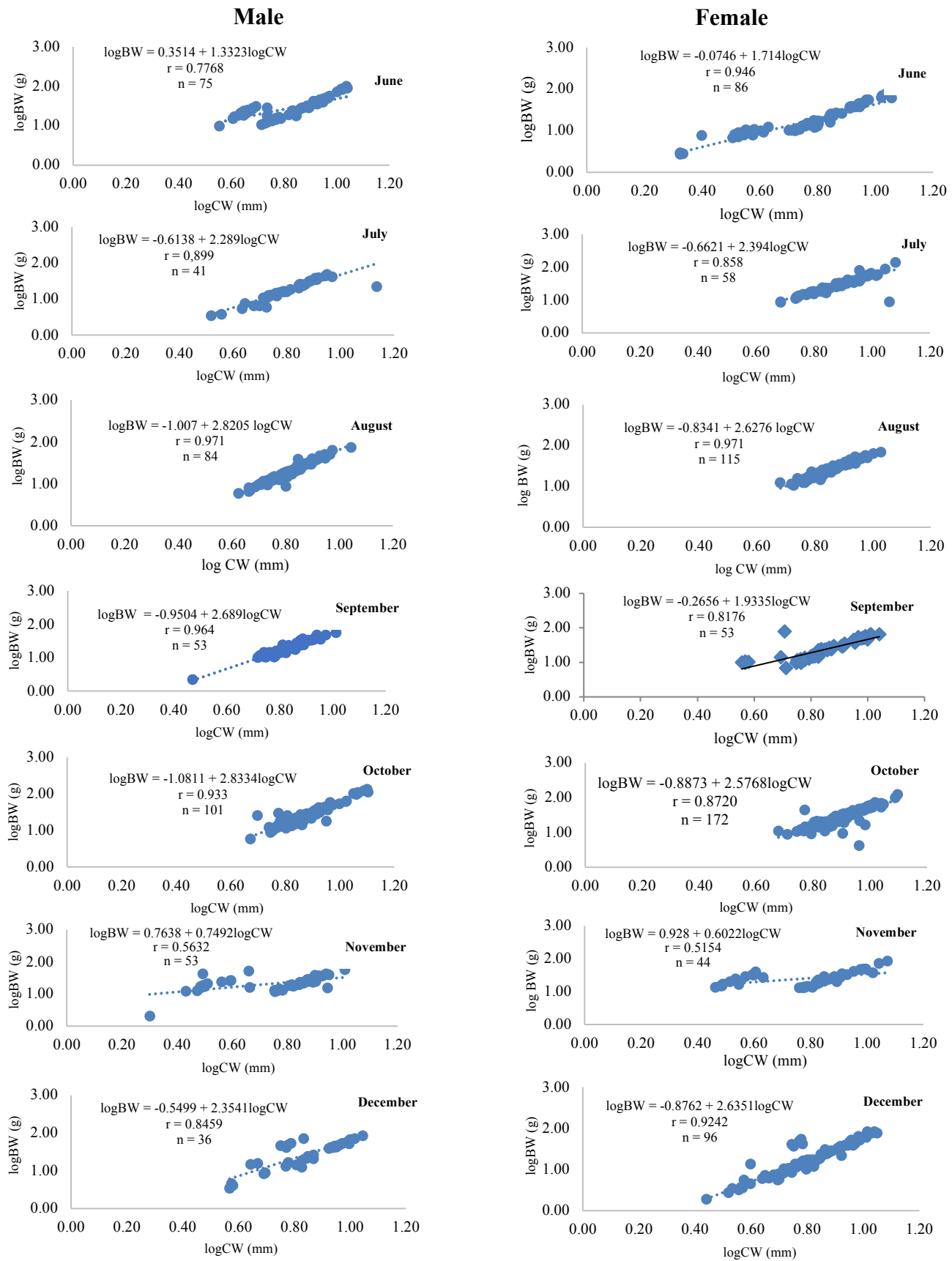


Figure 3. Monthly BSCs BW – CW relationship in Tiworo Strait waters, Southeast Sulawesi.

Table 3. Monthly condition factor (CF) index of male and female BSC in Tiworo Strait waters, Southeast Sulawesi.

Sex	Condition Factor (CF) Index						
	June	July	August	September	October	November	December
Male	3.022	-1.227	-0.697	-0.787	-1.007	1.508	-1.720
Female	-9.927	-1.597	-1.024	-3.592	-1.166	1.310	-0.837

Discussion

Sex ratio

Male and female BSC SR found in Tiworo Strait waters showed female was preponderated over male and those were significant different ($p < 0.05$), except in September was not significant different. It was found in November that male was preponderated over female, but it was also significant different (Table 1). It was clear that sampling locations for BSCs were habitat of juvenile and mature BSCs due to their monthly abundance (number) was high enough, and then at the end of mature stage and enter into adult stage that female BSCs particularly berried females will gradually move forward to much deeper saline water to ripe their eggs and released it up to hatch to be zoea larvae. La Sara et al. (2016a) also found similar phenomenon of BSCs in 2016. Similar study in Bantayan of Philippines also was reported by Ingles (1996) that BSC SR of male and female was 1 : 1.63. The SR of *P. segnis* population in Boushehr Coast (Persian Gulf) (Hosseini et al., 2014) and *P. pelagicus* population in Khuzestan coasts, Iran (Jazayeri et al., 2011) also showed females outnumbered male. Other study showed different with the present study in Tiworo Strait waters, for example Xiao and Kumar (2004) reported that fishermen in western Australia waters proportionally caught more males than that of females and males CW was also bigger than that of females. Furthermore, they explained that BSCs SR differences may correlate with condition onboard at the time of exploitation, where proportion of dead male BSCs was much higher than those of alive male BSCs. It was also demonstrated that male BSCs increased following increasing water depth from January to September and then decreased from October to December.

In spite of that, different in male and female BSCs SR were not caused by single factor, but among those environmental factors affecting SR interact each other and mutual affected. Ingles (1996) explained that BSC SR differences could be caused by different of “gillnet catchability”. Other factor is BSC behavior of each sex when attaining “maturity” stage. Xiao and Kumar (2004) detected yearly production variation of male BSCs caught in southern Australia waters decreased and increasing at the end of season. The effect of season on BSC distribution or other Portunidae resulted season migration. BSC juveniles occupy

coastal waters closed to mangrove forest with muddy substrate attaining mature stage (7 – 9 cm CW) of 8 – 10 months old (La Sara et al., 2016a, 2016b), then BSC females start to brood their eggs at ± 1 year old. They further leave inshore and move forward offshore in saline water to release their eggs (Potter and de Lestang, 2000; de-Lestang et al., 2003b), while BSC small sizes (juveniles) still occupy shallow waters. Such phenomenon cause BSC SR differences in several regions. Other study on *Callinectes sapidus* showed that salinity fluctuation may affect distribution according their sizes (Archambault et al., 1990; Ault et al., 1995), while temperature affect behavior and search for food. It may result different in number of BSC caught using collapsible pot which rely on fresh bait.

Growth pattern and condition factor

It is well known that BW is a function of CW or carapace length (CL) of BSCs or other crustacean which is generally expressed in the linear regression equation or parabolic equation. The BW – CW relationships for the crustaceans particularly BSC are usually used to express the crab population which is useful for the stock assessment (Gokce et al., 2006; Sangun et al., 2009), for the purpose of its exploitation (Josileen, 2011). The BW – CW relationships are regarded as more suitable for evaluating crustacean populations (Atar and Secer, 2003; Gokce et al., 2006; Sangun et al., 2009), and to determine growth patterns of BSCs (Hajjej et al., 2016; Afzaal et al., 2017).

The BSC growth happens when there is a moulting process (a hard exoskeleton or old carapace shed off in order to allow and accommodate increment of somatic mass). Quantifying patterns of BSC growth is difficult due to complications of incremental, discontinuous growth by moulting and the variety of life history strategies expressed by crustaceans (Josileen and Menon, 2005). After moulting, there is new carapace which is bigger than the old carapace. The CW (or CL) sizes increase in certain percentage from its original. In the few minutes, it is to be harder and is followed by increasing body weight (somatic mass increased in the BSC body) (La Sara, 2001a). Hartnoll (1982) explained that crustacean growth is dependent upon the duration of the moult interval and size increase at each moult (moult increment). It is why growth is a function of increment of BW and

moulting frequency (Hancock and Edwards, 1967). According to authors, it is also useful to investigate relative growth perhaps may determine changes in the form and size of the abdomen, pleopods, or chelipeds during growth progress.

Generally, BSCs experience moulting many times during the course of their life circle from larvae crabs to adult crabs stages. Moulting frequency is affected by several factors such as food availability, temperature, salinity, etc. Skinner (1985) had described well the process of the moulting of crabs, while Josileen and Menon (2005) had studied completely the growth of BSCs life circle from stage 1 up to stage 16 (more than 1 year old) in the laboratory. Increment of BSC BW and CW after moulting is affected by several factors, i.e. life stage (from megalopae, juvenile of 6 cm, mature of 6 - < 9 cm, up to adult of > 9 cm), food availability, environmental change, and interaction among other organisms – particularly its competitors. The BW – CW relationship of each stage is variable and figure out a unique growth pattern of each stage, namely following isometric pattern or allometric growth pattern which is shown by growth coefficient (b) as the result of regression analysis. Afzaal et al. (2018) showed that the growth patterns of *P. pelagicus* taken from Pakistani waters northern Arabian Sea is isometric.

Male and female BSCs found in Tiworo Strait waters were mainly mature stage (6 - < 9 cm), and followed by juvenile stage (< 6 cm) (Figure 3). BSC was belong to adult stage (> 9 cm) was relatively few. In the BSC population, juvenile growth rate to be mature stage has relative high growth coefficient (b). Generally, BW – CW relationship has strong coefficient correlation ($r > 0.75$). Josileen (2011) explained his study that the growth coefficient (b) values for BW – CW in males and females were 3.607 and 3.293, respectively. The results show a significant deviation from an isometric growth pattern.

Due to monthly BSC growth pattern in Tiworo Strait showed negative allometric growth that the healthy index of BSC was counted following “relative condition factor” (CF). Data of BW – CW relationship were derived to find out CF (Table 3). Those data showed linear relationship and strong influenced by growth coefficient (b), namely the higher of b the higher (healthier) of CF. Hajjej et al. (2016) found male and female CFs in Gabes Gulf of Tunisia were 0.00086 – 0.02287 and 0.0022 – 0.03453, respectively. Those CFs values are very small compare to CFs of male and female BSCs taken from Java sea ranging 5.04 - 8.88 and 4.22 - 11.70, respectively (Rohmayani et al., 2018).

Ideally, growth of crustacean follow isometric growth pattern which implies dimension of W increment will be followed proportionally by CW increment (shown by $b = 3$). The ideal such growth was mainly found in the study on several organisms, but in certain condition or in other species may show allometric growth pattern ($b \neq 3$), such as growth pattern of male and female BSCs in the present study namely negative allometric growth (Table 2). Those growth patterns revealed that BSC BW increment is slower than those of BSCs CW increment. Other study showed that BW of male BSCs were relative higher than those of female BSCs as shown by their growth coefficient (b) (Table 4). Hosseini et al. (2014) also found similar results in *P. segnis* in Persia Gulf up to reaching 10 – 12 cm CW sizes. Sukumaran and Neelakantan (1998) found significant body weight *P. pelagicus* increment at 11.5 cm CW size.

In the same CW ranges, male BSCs were higher of their BW than those of female BSCs. However, growth rate of both sexes in the present study did not follow those patterns (Figure 4; Table 4). The different result of male and female growth patterns in the present study with other studies may be due to BSC samples taken were dominated by BSCs mature and juvenile stages, while BSCs adult stage were few (Figure 4). Those BSCs have relative similar action when they seek for food in the same habitat, the different was probability they find food.

The different of those BSC growth patterns or other crustacean may be due to several factors. Data in Table 4 reveals that those growth coefficients (b) of BSCs vary and rely on regions (spatial). It is assumed that each region has own environmental condition (water quality such as temperature and salinity, substrate texture, food availability, species interaction, etc.) which all affect growth of BSCs. Food habits affecting BSC growth pattern mostly were influenced by temperature and salinity (Sukumaran and Neelakantan, 1998; Kangas, 2000). La Sara et al. (2002) explained that geographic condition of the location may also influence BSC growth pattern, due to food availability, water quality, texture substrate, and competitor organisms. There is strong evidence that abiotic variables related to the local climate have the strongest influence on this parameter (Araujo et al., 2012; Hajjej et al., 2016). Temporal (seasons and tides), sampling frequency, type and number of fishing gears used for sampling,

Table 4. The BSC growth coefficient (b) and correlation coefficient of BW – CW relationship from different regions.

No.	Sex	Growth Coefficient (b)	Correlation Coefficient (r)	Location	Source
1.	Male	3.26	-	Western Australia waters	Kangas (2000)
	Female	3.05	-		
2.	Male	3.22	0.88	Trang Province coastal, Thailand	Sawusdee and Songrak (2009)
	Female	3.18	0.87		
3.	Male	2.75	0.93	Bandar Abbas waters, Persia Gulf,	Kamrani et al. (2010)
	Female	2.74	0.88	Iran	
4.	Male	3.607	-	Mandapam coast, India	Josileen (2011)
	Female	3.293	-		
5.	Male	0.0224	0.847	Tiworo Strait waters, Southeast	La Sara et al. (2016a)
	Female	0.0238	0.838	Sulawesi	
6.	Male	3.0681	0.981	Gabes Gulf, Tunisia	Hajjej et al. (2016)
	Female	2.9043	0.979		
7.	Male	3.105	0.9680	Toronipa waters, Southeast Sulawesi	Muchtar et al. (2017)
	Female	2.926	0.9445		
8.	Male	2.56	0.899	Pakistani waters northern Arabia Sea	Afzaal et al. (2018)
	Female	2.96	0.939		
9.	Male	2.9883	0.9411	Lamongan waters, East Java	Rahman et al. (2019)
	Female	3.0535	0.9464		
10.	Male	3.2648	0.9643	Bungin Permai waters, Southeast	Permatahati et al. (2019)
	Female	2.7689	0.9407	Sulawesi	
11.	Male	2.664–14.310	0.457 – 0.956	Tiworo Strait waters, Southeast	Present study
	Female	4.187–11.064	0.642 – 0.970	Sulawesi	

etc. are confirmed strongly influencing number and size of BSCs caught which in turn affect analysis results of BW – CW relationship.

The data of the present study fully emphasizes and must be taken into account for fishery managers, local government, or mini plant owners to take some steps to avoid fishermen catch those small CW sizes (juvenile and mature stages). It is an alarm of BSC population in this waters that all parties must involve in regulation implementation on BSCs population as stated clearly in the Regulation of Minister of Marine Affairs and Fisheries No. 12/2020 (previously No.1/2015) regarding prohibiting the catch of BSC CW of < 10 cm and berried females. A study conducted in 2013-2014 came out with the conclusion of MLS for BSC to be caught is ≥ 10 cm CW (La Sara et al., 2016c).

Conclusions

The present study shows that temporal (monthly) SR changes generally females significantly preponderated over male which implies that stock opportunity of BSC reproduction was still high. The BSCs found were mainly mature stage (6 - < 9 cm) and then followed by juvenile stage (<6 cm), while mature stage (> 9 cm) was only few. The BW – CW relationship had strong enough correlation ($r > 0.75$) which was used for determining growth patterns of BSCs in this study location. Its growth patterns were negative allometric ($b < 3$). Those growth patterns may

relate to condition factors which figure the healthy index of BSCs in Tiworo Strait waters.

Declarations of interest

The author(s) declare that there is no conflict of interest with regards to the research, authorship and/or publication of this article.

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