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Comparative Analysis on Performance of Growth Patterns and Condition Factors of Blue Swimming Crabs (*Portunus pelagicus*) Caught from Waters of Fisheries Management Area (FMA) 713 and FMA 714 of Indonesia

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ABSTRACT

The blue swimming crab (BSC) fishery resources across waters of Southeast Sulawesi, which are connected to Fisheries Management Area (FMA) 713 and FMA 714, have been under significant pressure due to intensive fishing over the past 2–3 decades, and their habitat has experienced degradation. Several studies on BSCs have been conducted and so far have only focused on specific locations. The aim of this study was to compare growth patterns and condition factors (CF) of BSCs from the waters of Poleang, connected to FMA 713, and Lasongko Bay, connected to FMA 714. BSC samples were collected from catches of local fishermen using traps and gillnets, in July-August 2024. Each sample from study locations was sexed, carapace width (CW) was measured, and body weight (W) was recorded. The sex ratio data from both study locations indicated that males were preponderated over females, however the sex ratio was not significantly different ($X^2_{count} < X^2_{table}$). The relationship between W and CW of BSCs was analyzed using equation: W = a*CW^b, and condition factor (CF) was calculated using equation: CF = [(W)*100]/[CW^3]. Results showed that both male and female BSCs from each study location exhibited isometric growth patterns (b = 3) ($t_{count} < t_{table}$) and had a very strong correlation between W and CW (r > 0.95). The CF values for male and female BSCs from both study locations were fairly good and positive: CF values for BSCs from Poleang waters (FMA 713) were 7.5778 (male) and 7.6241 (female), which were relatively similar to those from Lasongko Bay (FMA 714), at 7.0150 (male) and 6.8207 (female). These data indicate that environmental conditions in both study locations are highly supportive for the growth and sustainability of BSC population. Therefore, the management of these BSC resources should be maintained or improved to ensure the sustainability and health of population.

INTRODUCTION

The blue swimming crab (BSC) (*Portunus pelagicus*) resources in Indonesia are one of the fisheries resources with significant economic value, both for local trade and export. These resources typically inhabit coastal waters from the intertidal zone to depths of up to 50m **(La Sara *et al*., 2016a)**. In the waters of Southeast Sulawesi, this species is generally found in areas with substrates dominated by fine sand mixed with mud, in front of mangrove forests, extending to areas with seagrass beds **(La Sara *et al*., 2016b; Permatahati *et al*., 2019)**. This species is intensively caught by small-scale fishermen throughout the year because the fishing areas are easily accessible by non-motorized boats or boats with engines of 5–6 HP. The fishing gear used includes traps and gillnets, which are easy to operate **(La Sara & Astuti, 2015; La Sara *et al*., 2019)**.

Intensive fishing without size selection (minimum legal size) and without a quota limit has been conducted over the past 2 decades as demand for this species has increased with premium prices. Such fishing practices have led to overexploitation, particularly of adult BSCs that are ready to reproduce, resulting in a significant decline in their numbers. Juvenile and immature BSCs, or those not yet at reproductive size, are often caught before they have a chance to reproduce, further exacerbating the condition of wild BSC stocks. Another issue is the destruction of BSC habitats, especially for juvenile and immature BSCs, which are located near or adjacent to mangroves and seagrass beds. Mangrove forests, which serve as nursery grounds for juvenile BSCs, have been converted into residential areas, and shipyards/boat jetties. Land clearing for agriculture has contributed sediment to coastal areas, covering seagrass beds and creating mud-dominated substrates that are unfavorable for BSCs and other crustaceans **(La Sara *et al*., 2016b; 2017)**. This situation poses a serious threat to the sustainability of the BSC population, as indicated by the decreasing size of BSCs caught, with carapace widths (CW) of less than 6cm, the fishing grounds becoming more distant, and the catch per unit effort (CPUE) declining **(Zairion *et al*., 2015; La Sara *et al*., 2016a; 2017)**.

Although several studies have been conducted in the waters of Southeast Sulawesi, most have focused on specific locations, such as the design of selective trap fishing gear **(La Sara *et al*., 2016a)**, the reproductive biology of BSCs **(La Sara *et al*., 2016b; Basri *et al*., 2017)**, BSC population parameters **(La Sara *et al*., 2017; Muchtar *et al*., 2017)**, BSC stock status **(La Sara *et al*., 2019; Permatahati *et al*., 2020)**, the relationship between W and CW of BSC **(Permatahati *et al*., 2019; Astuti *et al*., 2020b)**, the spatial and temporal abundance structure of BSCs **(Astuti *et al*., 2020a)**, and the spatial and temporal composition and sex ratio of decapods **(Astuti *et al*., 2022)**. The current study covers water areas with distinct characteristics, specifically waters connected to FMA 713 and other waters connected to FMA 714. The objective of this study was to compare the growth patterns and condition factors of BSCs from the waters of Poleang (connected to FMA 713) and Lasongko Bay (connected to FMA 714). The results of this study serve as a source of information for forming sustainable management straegies of this species to ensure that the capture of these resources is regulated in accordance with principles of fairness and sustainability.

MATERIALS AND METHODS

1. Sampling location

The waters of Poleang and Lasongko Bay, as the sampling locations for BSCs (*P. pelagicus*), are directly connected to FMA 713 and FMA 714, respectively. These locations were selected considering that the geographical position of each site is influenced by respective of the hydrological conditions of these FMAs (Fig. 1). Both areas are important fishing grounds for BSCs, heavily utilized by small-scale fishermen.

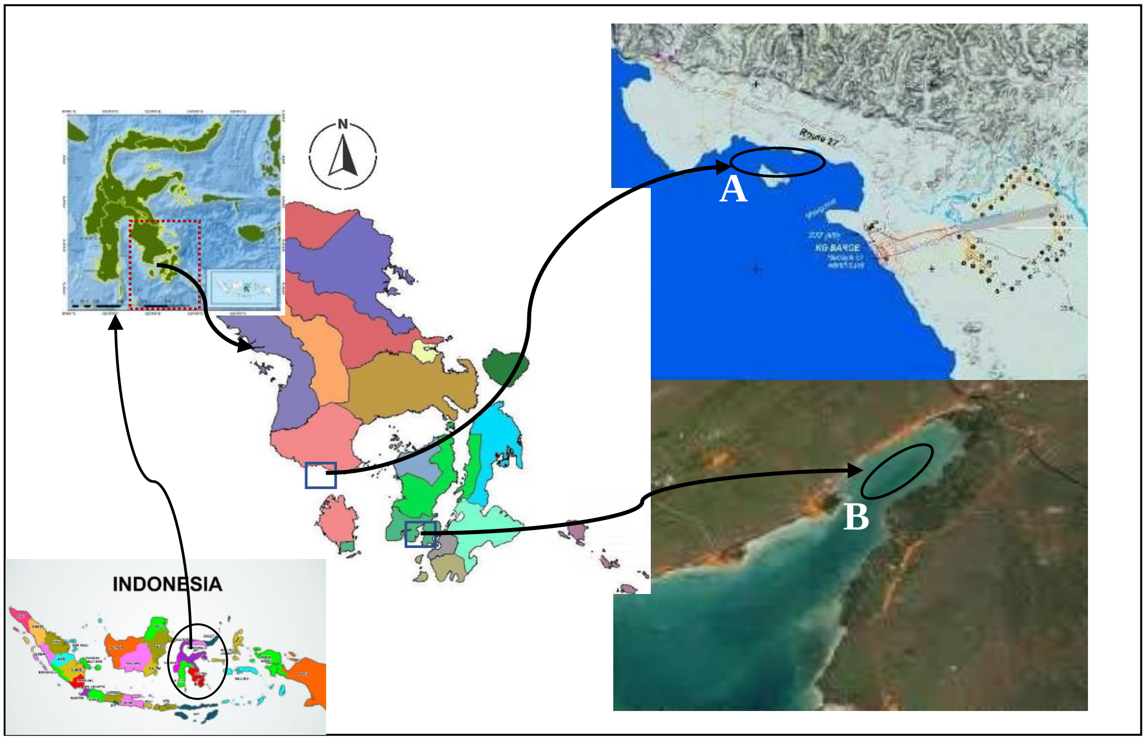

Fig. 1. Map of BSC sampling locations in Poleang waters connected to FMA 713 (A) and in Lasongko Bay waters connected to FMA 714 (B), Southeast Sulawesi, Indonesia (black oval circles represent sampling locations)

Poleang waters (A), to the west and south, are directly connected to the Bone Strait, influenced by the hydro-oceanographic conditions of FMA 713. This area is characterized by scattered coral reefs, with seagrass growing in waters at depths of 5–7m. The substrate of this location is generally fine sand mixed with mud. To the north and east, the area is bordered by the mainland of Bombana Regency. In Lasongko Bay (B), mangroves dominate the western part, with a substrate of sand mixed with a small amount of mud. Coral reefs with sandy substrates are found in the central and eastern parts of these waters. The bay mouth to the south, directly connecting to the waters of Baubau and the Spelman Strait, which are influenced by the hydro-oceanographic conditions of FMA 714. Fishermen in both locations typically use collapsible crab pots and gillnets to catch crabs (Fig. 2). Sampling of BSCs was conducted during July–August 2024.

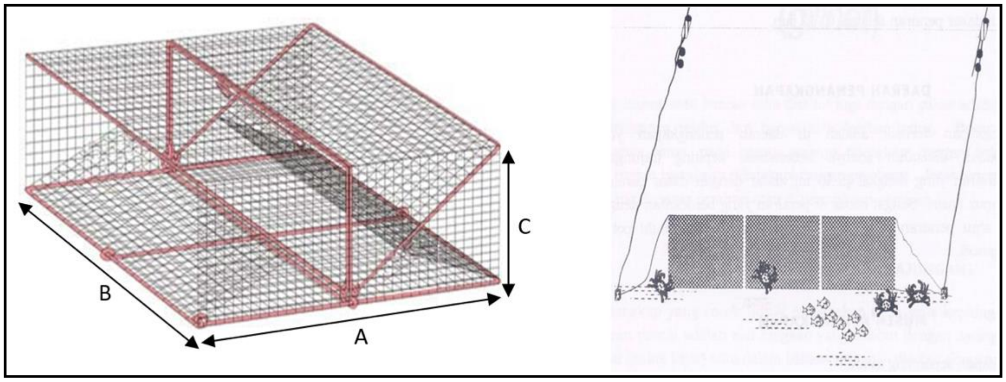

Fig. 2. Rectangular collapsible crab pot on the left and bottom gillnet on the right used for BSC sampling in Poleang waters connected to FMA 713 and in Lasongko Bay waters connected to FMA 714, Southeast Sulawesi, Indonesia

2. Sampling procedure

BSC sampling data from each location were obtained from fishermen or BSC collectors every month. The BSCs were immediately sexed based on abdominal morphology (Fig. 3), weighed using an electronic scale (with 1g accuracy), and the CW was measured with a ruler (with 1 cm accuracy) (Fig. 4).

Fig. 3. Abdomen morphology of BSC **(A)** male and **(B)** female sex

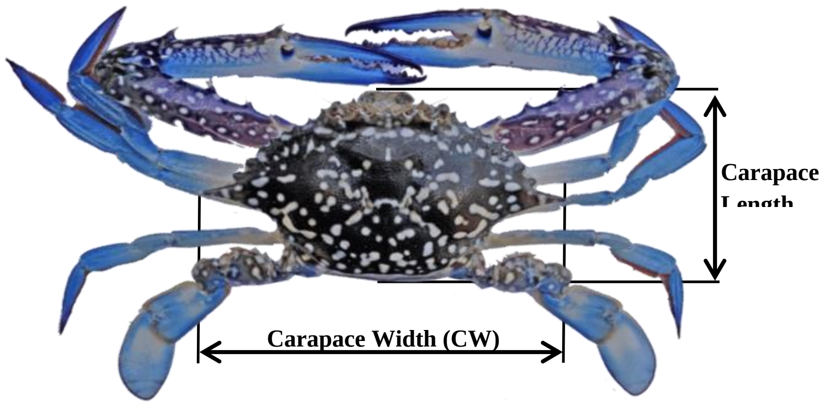

Fig. 4. Measurement of some morphometric aspects of BSC

3. Data analysis

Sex ratio of BSC

The number of BSCs of each sex (male and female) collected from each location was counted and analyzed using the following formula:

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

The significance of the BSC sex ratio was tested using the Chi-square (X^2) test (α = 0.05) **(Sudjana, 1989)**, with the formula:

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

Where, SR=sex ratio, X^2=Chi-square, O=BSC male and female frequency observed, E=BSC male and female frequency expected.

Growth pattern (b) and condition factor (CF)

In fisheries biology, BSC growth patterns are determined by the growth coefficient (b) of the W and CW relationship, analyzed using the growth equation: W = a*CW^b; where W = body weight, CW carapace width, a = intercept of CW or initial growth coefficient, and b = slope or growth coefficient, which represents the growth pattern.

Typically, crustaceans particularly BSC exhibit isometric growth patterns (b = 3), meaning that the increase in W is proportional to the increase in CW. However, when crustaceans or BSCs follow an allometric growth pattern ($b \neq 3$), it is classified as either positive allometric ($b > 3$), where the increase in W is faster than the increase in CW, or negative allometric ($b < 3$), where the increase in W is slower than the increase in CW. To determine whether the growth patterns of male and female BSCs in each study location are isometric or allometric, a t-test was used.

Since the male and female BSCs in both study locations followed an isometric growth pattern (b = 3) ($t_{count} < t_{table}$), the CF of the BSCs was analyzed using Le Cren's equation (1951), as follows: CF = [(W)*100]/[CW^3], where W = average body weight (g), CW = average carapace width (cm), a and b = intercept and growth coefficients, respectively from the W – CW relationship **(Noori *et al*., 2015; Astuti *et al*., 2020b)**.

RESULTS

1. Sex ratio of BSC

Randomly selected samples of BSCs collected from fishermen or BSC collectors in each study location showed a sex ratio where males preponderated over females (Table 1). However, the Chi-square (X^2) test (α = 0.05) indicated that the difference in sex ratio between male and female BSCs was not statistically significant ($X^2_{count} < X^2_{table}$).

Table 1. Male and female BSC sex ratio in Poleang waters (FMA 713) and Lasongko Bay waters (FMA 714), Southeast Sulawesi, Indonesia

No.	Location	Sex ratio (Male : Female)
1.	Poleang waters (FMA 713)	1.188 : 1^{ns}
2.	Lasongko Bay waters (FMA 714)	1.025 : 1^{ns}

ns = not significantly different

2. Growth pattern (b) and condition factor (CF)

The relationship between W and CW in BSCs or the relationship between W and total length (TL) in some fish species, is highly beneficial for fisheries biology and has important applications in BSCs fisheries management. In this study, the W – CW relationship of the BSCs from each location, separated by sex, showed a very strong correlation (r > 0.95) (Fig. 5). Fig. (5) shows that both male and female BSCs from the 2 study locations exhibit an isometric growth pattern (b = 3) ($t_{count} < t_{table}$). Therefore, the CF of the BSCs was analyzed using Le Cren's equation: CF = [(W)*100]/[CW^3]. The growth coefficient (b) of BSCs (Fig. 5) was used to calculate the CF index (Table 2).

Table 2. The CF of male and female BSCs in Poleang waters (FMA 713) and Lasongko Bay waters (FMA 714), Southeast Sulawesi, Indonesia

No.	Location	Sex	Condition factor (CF)
1.	Poleang waters (FMA 713)	Male	7.5778
		Female	7.6241
2.	Lasongko Bay waters (FMA 714)	Male	7.0150
		Female	6.8207

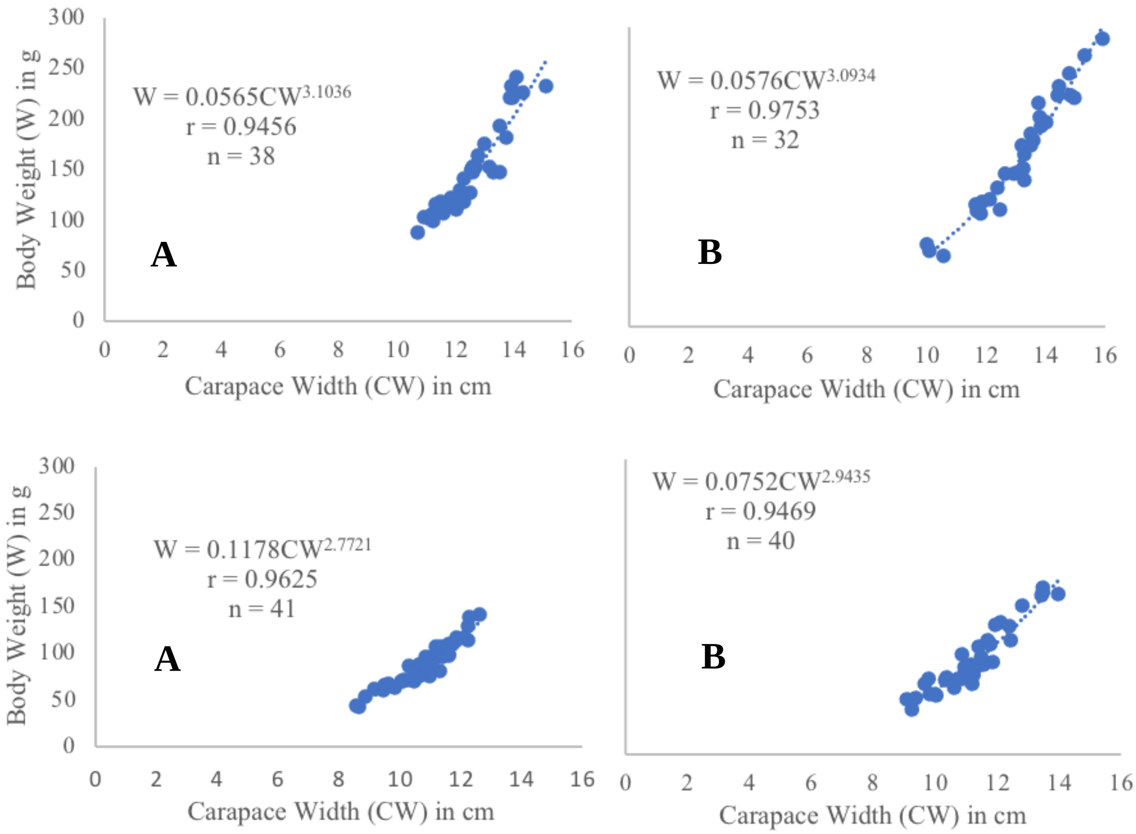

Fig. 5. The W – CW relationship of BSCs in Poleang waters (FMA 713) (above) and Lasongko Bay waters (FMA 714) (below), Southeast Sulawesi, Indonesia (A = male; B = female)

DISCUSSION

1. Sex ratio of BSC

One of the key parameters in population ecology of fishery species is determining the sex ratio of males and females, as this directly affects reproductive dynamics, population growth potential, and community structure of a species, including the BSC population. The male-to-female sex ratio is a critical factor for policy makers because it has a direct impact on population sustainability and ecosystem balance. A healthy BSC is indicated by a balanced sex ratio, typically around 1:1. Any deviation from this 1:1 sex ratio can disrupt the population dynamics of the BSCs, the balance of the aquatic ecosystem, and other species within the food chain or food web **(La Sara *et al*., 2024)**.

In BSC populations, differences in sex ratios (sex ratio bias) can occur depending on life stages, especially in juvenile, pre-adult, and adult phases. This happens because each sex at these stages has different preferences, particularly in the adult male and female phases. Generally, adult female BSCs, especially those carrying eggs (berried females), tend to migrate to deeper offshore waters to spawn, while adult males typically remain in coastal waters along with juvenile and pre-adult males and females. The sex ratio data from this study show that the number of male BSCs preponderated over female BSCs, however, Chi-square (X^2)-test results indicate that the difference was not significant (Table 1). **Astuti *et al.* (2020a)** found that the sex ratio of juvenile, mature, and adult BSCs in Tiworo Strait waters generally showed a male-dominant ratio at certain locations, while other areas showed no regular pattern. A study on commercial BSC fisheries in Western Australian waters revealed that variations in male and female sex ratios occurred, but the pattern remained consistent across different years **(Johnston *et al.*, 2011)**. Several studies had explained that differences in sex ratio can be influenced by spatial factors, such as variations in habitat characteristics **(La Sara *et al.*, 2016b)** and geographical position **(Kumar *et al.*, 2000)**, as well as temporal factors in the study location, such as seasonal changes and spawning seasons **(Potter & de Lestang, 2000; de Lestang *et al.*, 2003)**. Other influencing factors include differences in lifespan, migration patterns, food availability, and feeding behavior **(Xiao & Kumar, 2004; La Sara *et al.*, 2016b)**. Additional factors affecting the sex ratio of BSCs include fishing methods, fishing frequency, gear types used, and fishermen's skills **(Ingles, 1996; Xiao & Kumar, 2004; La Sara *et al.*, 2016a)**, as well as population dynamics of growth, natural and fishing mortality **(La Sara *et al.*, 2016b, 2017)**. **De Lestang *et al.* (2010)** explained that water parameters such as salinity and temperature may influence the reproductive cycle and activities of BSC, as well as their distribution patterns, as observed in Cockburn Sound, Australia **(Kumar *et al.*, 2000)**.

Study findings from several regions show similarities to this study, for example, the sex ratio of juvenile male to female BSCs in southern Australian waters was 1:0.71 **(Xiao & Kumar, 2004)**, in southern Indian waters it was 1:0.961 **(Dineshbabu *et al.*, 2008)**, and in Trang waters, Thailand, it was 1.17:1 **(Nitiratsuwan *et al.*, 2013)**. It is suspected that the lower number of female BSCs during sampling is due to the spawning period, during which adult females migrate to release their eggs **(Sumpton *et al.*, 1994)**. Other studies with different sex ratio findings compared to this study include those in Bantayan waters, the Philippines **(Ingles, 1996)**, Bandar Abbas, the Persian Gulf (**Kamrani *et al.*, 2010)**, Leschenaukt Estuary, Australia **(Potter & de Lestang, 2010)**, and Tiworo Strait, Indonesia **(La Sara *et al.*, 2016b)**. The sex ratio data from these studies indicate that many parameters affect it, especially spatial and temporal factors for the study location, the internal physiological conditions of the BSCs, fishing gear and methods, water quality parameters (particularly temperature and salinity), habitat conditions, sampling frequency, and fishermen's skill in using the gear employed.

2. Growth pattern (b) and condition factor (CF)

Growth patterns in crustaceans, particularly BSCs (*Portuns* sp.) are used to express the status of their population **(Atar & Secer, 2003)**, which is valuable for stock assessment **(Gokce *et al*., 2006; Sangun *et al*., 2009)**, determining the level of exploitation **(Josileen, 2011)** and understanding growth patterns **(Hajjej *et al*., 2016; Afzaal *et al*., 2017)**. The growth pattern of BSCs, determined by the value of b in the exponential W-CW equation (or simple regression equation), has significant implications for the management of BSC fisheries. The growth pattern (b value) can also be used to assess the impact of fishing activities on the BSC population. Additionally, the b value, which indicates the true b of BSCs, explains the population's health and environmental status and can be used to determine the fishery's potential productivity.

In this study, the b value follows an isometric growth pattern (b =3) (X^2_{count} < X^2_{table}), indicating that the BSC populations in both study locations are in a healthy condition, with balanced ecosystems and stable, productive growth. The W-CW growth relationship for both male and female BSCs at both study sites is very strong ($r > 0.95$) (Fig. 5). Other studies in different waters showed varying results. For example, BSCs caught in Pakistani waters in the northern Arabian Sea followed an isometric growth pattern **(Afzaal *et al*., 2017)**. In western Australian waters **(Kangas, 2000)** and the coastal waters of Trang, Thailand **(Sawusdee & Songrak, 2009)**, the b value for males and females is >3, while in Bandar Abbas, the Persian Gulf waters, the b value is <3 **(Kamrani *et al*., 2010)**. However, all these studies showed a relatively strong correlation ($r > 0.85$). Variations in b and r values in BSCs are due to several factors, mainly age, genetic derivation, and seasonal temperature variations, which significantly affect feeding activities and growth rates **(Kangas, 2000)**. Although temperature and salinity were not measured in this study, both parameters influence BSC growth. **La Sara *et al*. (2016b)** explained that water temperatures ranging between 30-33°C and salinity between 26-32ppt were suitable and support feeding activities and growth rates of BSCs. BSCs have also been found in waters with lower temperatures, such as in Dawesville Channel, Australia, where temperatures are between 24-25°C **(de Lestang *et al*., 2003)**. Direct observations suggest that differences in sex, growth stages, and the loss of body parts significantly contribute to the b and r values. The b and r values from this study indicate that natural resources such as food and habitat support BSC growth well. Therefore, managing the BSC population should focus on maintaining the habitat conditions of these 2 water locations, while controlling fishing activities to ensure the environment continues to support BSC growth, promoting a stable and sustainable BSC population. When the b of BSCs shows b < 3, it indicates that the habitat lacks food resources or is overexploited. Thus, management measures should be implemented immediately, such as (1) limiting fishing quotas to maintain the population as mandated in Government Regulation (PP) No. 11/2023 on Quota Based Fishing, (2) Implementing Minimum Legal Size (MLS) regulations, as outlined in the Ministry of Marine Affairs and Fisheries Regulation No. 7

of 2024 on the Management of Lobster (*Panulirus* spp.), Crab (*Scylla* spp.), and Blue Swimming Crab (*Portunus* spp.), which prohibits the capture of berried female BSCs and those with a CW <10cm or W <60g (Article 12, Paragraph 1, Clauses 1 and 2), and (3) Enforcing temporary closures during the spawning season or permanently banning unselective fishing gear that damages aquatic ecosystems.

The b of male and female BSCs from both study locations can be quantitatively explained through the CF. The CF values derived from the exponential W- CW equation (Table 2) reflect the condition of the BSC fishery and the aquatic environment. There is a strong relationship between the b value and the CF value. **Astuti *et al*. (2022)** explained that "the higher the b, the higher (healthier) the CF. The CF values for BSCs (*P. segnis*), both male and female, in Gabes Gulf, Tunisia, ranged from 0.00086–0.02287 for males and 0.0022–0.03453 for females **(Hajjej *et al*., 2016)**. These small CF values indicate that the population and environment were under considerable pressure. In contrast, the CF values for male and female BSCs from the 2 study locations in this study (Table 2) were relatively similar and quite high: 7.5778 (males) and 7.6241 (females) in Poleang waters (FMA 713), and 7.0150 (males) and 6.8207 (females) in Lasongko Bay waters (FMA 714). These CF values differ somewhat from the CF values of male and female BSCs (*P. pelagicus*) in the Java Sea, which ranged from 5.04-8.88 for males and 4.22-11.70 for females **(Rohmayani *et al*., 2018)**. The high CF values in this study indicate a healthy BSC population, suggesting that BSC fisheries are within sustainable limits, while the aquatic environment is in good condition, with sufficient food resources available to support growth.

CONCLUSION

In this study, the number of male BSCs preponderated over female BSCs, but the results of the X^2 test showed no significant difference. This balance in the sex ratio indicates that the BSC population in these study locations is considered healthy. The W-CW relationship for both male and female BSCs in both study locations showed a very strong correlation (r >0.95), and all exhibited an isometric growth pattern (b =3). These values suggest that the growth of BSCs in these waters is very good, as the necessary food is sufficiently available, and their habitat is highly supportive, as evidenced by the relatively high CF values: 7.5778 (male) and 7.6241 (female) in Poleang waters (FMA 713), and 7.0150 (male) and 6.8207 (female) in Lasongko Bay waters (FMA 714).

Based on the data obtained, it is recommended that the population and habitat of BSCs at the study locations be maintained and protected from factors that may threaten the BSC population. For example, BSCs with a CW of <10 cm should not be harvested, berried female crabs should not be caught, and unselective fishing gear should not be used. Additionally, the BSC habitat in these waters should be preserved by preventing mangrove deforestation, sedimentation that covers seagrass beds, and substrates dominated by mud. This is intended to ensure the sustainability of the BSC population.

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