Biological condition and carapace width frequency distribution of blue swimming crabs (*Portunus pelagicus*) in Gresik and Lamongan, East Java

M A Rahman1,2, F Iranawati1,2, A B Sambah1,2, D G R Wiadnya1,3

1Faculty of Fisheries and Marine Science, Universitas Brawijaya
2MEXMA Research Group, Faculty of Fisheries and Marine Science, Universitas Brawijaya
3Ichtyo-fauna Research Group, Faculty of Fisheries and Marine Science, Universitas Brawijaya

Email: arifelzain@ub.ac.id

Abstract. Crabs, including the blue swimming crab (*Portunus pelagicus*), are one of the top five Indonesian fisheries export commodities. The blue swimming crab (BSC) is captured by various fishing gears that are indicated to threaten the sustainability of BSC resources. The aims of this study were to determine the biological condition of BSC by fishing gear, especially carapace width and weight relationship; sex composition and berried or non-berried female (BEF/NBEF); and carapace width distribution. BSC samples were randomly collected from four fishing bases in Gresik and Lamongan, East Java, Indonesia, from July to September 2018. The study found allometric and isometric BSC growth patterns at Gresik and Lamongan, respectively. Sex ratio of male and female crabs was balanced (1:1) with 16% of BEF in Gresik, while in Lamongan, there were more females than males (1:1.6) with 20% of BEF. Overall, catches were dominated by the size class with 11-12 cm carapace width and 70-90 g in weight. The carapace width distribution of indicated that catches from traps were dominated by BSC with of carapace width >10 cm (94%), (according to Ministerial Decree of Marine Affairs and Fisheries number 56/2016, >10 cm of carapace width is the legal size for BSC capture). Meanwhile, BSC catches from gillnets and mini trawls comprised 69% and 52% in the legal size class (>10 cm carapace width), respectively. Promoting traps as a BSC fishing gear can support the implementation of the ministerial decree in the field.

1. Introduction

The blue swimming crab (BSC; *Portunus pelagicus*) is one of the high value fishery export commodities in Indonesia. During the period of 2012-2017, the export value of BSC increased by 6.15% per year [1]. [2] stated that the BSC can be found in a wide range of depths and is widely distributed across the waters of many nations, including Japan, Philippines, Malaysia, Brunei Darussalam, Indonesia, Australia, Fiji islands, and Africa. In Indonesia, during the period 2005-2014, the highest crab production came from Fisheries Management Area (*Wilayah Pengelolaan Perikanan*, WPP) Republic of Indonesia 712 (Java Sea) where the average production reached 16,774 tons, which was approximately 44% of total crab production in Indonesia [3].

Management of a fishery resource requires information on the target species population biology. For crustaceans this includes the carapace length/width-weight relationship, sex composition, and size
distribution [4,5]. Moreover, to ensure the sustainability of BSC fisheries in Indonesia, the Ministry of Marine Affairs and Fisheries (MMAF) has implemented Ministerial Decree of Marine Affairs and Fisheries number 1/2015, which was then revised by Decree number 56/2016. This decree states that individual BSC can be legally captured when they are not carrying eggs, and have attained a size of >10 cm carapace width (CW) or >60 g in weight (W).

The BSC is commonly captured using several gear types, including collapsible traps, bottom gillnets, and mini trawls [6]. Research on BSC population biology has been carried out in several Indonesian waters [4,7–10]; however, additional information was also needed to support the establishment of holistic BSC management. In addition, three years after implementation of the first BSC regulation (i.e. decree number 1/2015), little is known about the condition of BSC captured using different fishing gear types. The aims of this study were to determine biological condition, especially carapace width-weight relationship; sex and berried/non-berried female catch composition; and carapace width distribution of BSC, for each fishing gear commonly used in Gresik and Lamongan, two BSC fishing regions in East Java, Indonesia.

2. Materials and Methods
The research was conducted at four fishing bases in Gresik (two sites) and Lamongan (two sites). Data were randomly collected from middlemen (locally known as pengepul) every day, except Fridays, from July to September 2018.

Carapace width was measured using vernier callipers (precision 0.01 mm), while digital scales (precision 0.1 g) were used to weigh each individual BSC. The sex was identified by observing the abdomen of each BSC (Figure 1) as well as recording the berried/ovigerous females (BEF).

Carapace width to weight relationship was determined using a cubic or power curve [11] with formula \( W = a \times CW^b \), where \( W \) is the weight (g), \( CW \) is the carapace width (cm), \( a \) and \( b \) are regression coefficients. If \( b \) is close to 3, the growth pattern is isometric [11,12]. The relationship then was tested using t-test to determine whether the growth of BSC was allometric or isometric.

Sex ratio was analysed using the Chi-square test \( (X^2) \) with the equation \( X^2 = \sum(O-E)^2/E \), where \( O \) is the observed value, and \( E \) is the expected value [13]. The expected sex ratio of male:female was 1:1 (equal or balanced). Data on berried/non-berried females, and carapace width distribution per fishing gear were tabulated and analysed descriptively.

Figure 1. Abdomen of female (a) and male (b) blue swimming crabs (BSC) [14]
3. Results

3.1. Carapace width-length relationship
Data were collected on a total of 10,391 blue swimming crabs (BSC) during the study period. At both Gresik and Lamongan, the value of the coefficient $b$ was higher for male than female BSC (Table 1), indicated that at the same size in terms of carapace width (CW), male crabs tended to be heavier than females. The growth pattern based on the $b$ coefficient was allometric positive for male BSC in Lamongan and allometric negative for female BSC in Gresik. The combined sex growth patterns were allometric negative in Gresik and isometric in Lamongan.

Table 1. Carapace width-length relationship ($W = a\cdot CW^b$) for blue swimming crabs collected from July to September 2018 at study sites in East Java, Indonesia

| Sex   | Variable | Location     |
|-------|----------|--------------|
|       |          | Gresik       | Lamongan    |
| Male  | $a$      | 0.067        | 0.061       |
|       | $b$      | 3.010*       | 3.054*      |
|       | $R^2$    | 0.877        | 0.896       |
| Female| $a$      | 0.098        | 0.069       |
|       | $b$      | 2.817*       | 2.988ns     |
|       | $R^2$    | 0.837        | 0.886       |
| All   | $a$      | 0.081        | 0.069       |
|       | $b$      | 2.911*       | 2.996ns     |
|       | $R^2$    | 0.854        | 0.894       |

* significant ($p < 0.05$) means $b \neq 3$ (allometric)
ns not significant ($p > 0.05$) means $b = 3$ (isometric)

3.2. Sex composition and berried/non-berried females (BEF/NBEF)
Overall, more females were captured than males (Table 2), with the number of females consistently higher than males throughout the study period (Figure 2). However, the ratio between male and female BSC was not statistically different from 1:1 in Gresik (1:1; $X^2 = 0.430; df = 1; p = 0.512$), while in Lamongan there were 22.5% more females than expected (1:1.6; $X^2 = 288.2; df = 1; p < 0.001$). The percentages of female crabs captured by fishermen while carrying eggs (BEF) in Gresik and Lamongan were 16% and 20% respectively (Table 2).

Table 2. Sex composition, sex ratio, and number of females bearing eggs (BEF) in blue swimming crabs (BSC) collected from July to September 2018 at study sites in East Java, Indonesia

| Location | Frequency (individual) | Sex Ratio | BEF (individual) |
|----------|------------------------|-----------|-----------------|
|          | Female    | Male      | Female | Male     |          |
| Gresik   | 2331      | 2376      | 1      | 1        | 383      |
| Lamongan | 3482      | 2202      | 1.6    | 1        | 693      |
| Total    | 5813      | 4578      | 1.3    | 1        | 1076     |
3.3. Carapace width and weight frequency distribution per fishing gear

In Lamongan, most sampled BSC were captured by traps (locally known as *bubu*), gillnets, and mini trawls (locally known as *mayang*), while in Gresik, the BSC samples were predominantly captured by gillnets and mini trawls. Over the whole study period, the largest percentage of samples recorded were BSC captured by mini trawls (Figure 3).

![Figure 3. Catch composition of BSC for each fishing gear](image)

**Figure 2.** Frequency of female and male BSC captured during the study period in 2018

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**Figure 3.** Catch composition of BSC for each fishing gear

Overall, the catch was dominated by the size class with 11-12 cm carapace width (CW) (Figure 4a) and 70-90 g weight (W) (Figure 4b). According to the Ministerial Decree of Marine Affairs and Fisheries number 56/2016, the legal size for BSC capture is CW >10 cm or W >60 g. Looking at the CW alone, 94% of the BSC catch from traps met the regulation with an average CW of 12.15±1.38 (mean±SD). Meanwhile, a much lower proportion (69% and 52%, respectively) of the BSC catch from gillnets and mini trawls met the regulation (Figure 4a), with CW = 10.61±1.38 (mean±SD) for gillnets and CW = 9.95±1.74 (mean±SD) for mini trawls. The results based on weight were similar, with 95%, 77%, and 56% of the catch from traps, gillnets, and mini trawls, respectively, meeting the ministerial regulation criterion of W > 60 g (Figure 4b).

Furthermore, traps are a passive fishing gear, and most captured animals will remain alive inside the trap until they are collected. However BSC caught in gillnets and mini trawls are mostly injured or die in the fishing gear and therefore undersized individuals or berried females could not be released.
back into water [15,16]. The use of traps would enable berried females (BEF) to be transferred alive into a temporary shelter and given sufficient time to release their offspring before being marketed. To avoid the capture of undersized BSC, it is also possible tomodify trap construction by adding an escape gap/vent to let undersized BSC escape from the trap, thus minimising illegal capture and the need to release undersized individuals. Therefore, promoting traps as a BSC fishing gear could enable implementation targets for the ministerial decree to be met at the field level as well as helping to maintain BSC populations and thus the sustainability of the BSC fishery.

**Figure 4.** Carapace width (a) and weight (b) frequency distribution of BSC catches by fishing gear; red line indicates legal size (carapace width or weight) of BSC according to Ministerial Decree 56/2016
4. Discussion

The value of the size-weight relation coefficient \( b \) was higher for male BSC than for female BSC in both study locations. Several studies on BSC growth patterns at different locations also report different values of the coefficient \( b \) for male and female crabs [8–10]. This variation could be affected by internal and external factors such as sexual dimorphism, maturity, food supply, temperature, and salinity [4]. The difference in growth between male and female crabs at both locations was likely due to the differences in their feeding behaviour. Female crabs have low intensity of feeding or even stop eating when in berried condition [17].

Differences in sex ratio can be affected by breeding season, migration, and habitat preferences [18–20]. Male crabs mostly live in coastal and estuarine areas, while female crabs will often migrate into deeper and higher salinity waters when they reach maturity [21]. It is suggested that the noticeable difference in sex ratio between the sites, with a female-biased composition in Lamongan, but not in Gresik, may be related to the fishing gear used by the fishermen. Female crabs were mostly captured by traps (1902 individuals, representing 54.6% of female crabs sampled in Lamongan) that were operated at depths of >10 m. In addition, the gap between the number of male and female crabs increased in August. This finding was similar to the statement in [8] that the proportion of female BSC increases in January, April, and August. It was suggested that in August, females started to migrate into coastal waters after mating and, therefore, entered into the catchability area of fishing gears operated in coastal waters.

It is suggested that the high proportion of BEF may have been affected by the siting of the BSC fishing grounds in Gresik and Lamongan, where fishing gear were operated at depths of >5 m. According to [22], the percentage of BEF in the coastal waters of East Lampung was on average 26.05% at depths of 5-10 m and 24.67% at depths over 10 m. In addition, female BSC in berried condition were found every month during the study period. Other studies also report finding BEFs every month, although the peak breeding season (month) was different from one location to another [23,24]. The high number of BEF captured should be considered as an alarm call for BSC resources, as the excessive capture of BSC BEFs could lead to recruitment overfishing [22]. Management strategies are needed to address this problem and ensure the sustainability of BSC fisheries. Taking into account that, overall, the mean BEF CW was 11.38±1.21 (mean±SD), establishing temporary shelters for captured BEF to breed before being sold by fishermen is one suggestion which could help sustain BSC resources. After the eggs are released and have hatched into planktonic zoea larvae, the female crabs could be taken and sold, while the larvae could be released into the waters around the shelter or in a suitable place where they could develop and grow.

5. Conclusion

The study observed that male blue swimming crabs (BSC) were, on average, heavier than females of the same size (carapace width) in both locations. The growth pattern of BSC was allometric negative in Gresik and isometric in Lamongan. The sex ratio was balanced in Gresik but female-biased in Lamongan. The overall total percentage of berried females (BEF) from both location combined was 19%. Of the three fishing gear types used, traps performed best in meeting the legal size requirements for BSC capture compared to gill nets and mini trawls, and furthermore could enable the release of undersized BSC and enable BEF to release their progeny before being consumed. to be released. Promoting traps as a BSC fishing gear is one practical measure which could support the implementation of the ministerial decree on BSC minimum size/weight limits in the field.

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