Morphometric character variation of the blue swimming crab (*Portunus pelagicus* Linnaeus, 1758) population in western and eastern part of Java Sea

Zairion1,2,*, Fauziyah1, E Riani1, A A Hakim1, A Mashar1, H Madduppa3 and Y Wardiatno1,2,4

1 Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University (Bogor Agricultural University), IPB Dramaga Campus, Bogor 16680, Indonesia
2 Center for Coastal and Marine Resources Studies, IPB University (Bogor Agricultural University), IPB Baranangsiang Campus, Jalan Raya Pajajaran, Bogor 16143, Indonesia
3 Department of Marine Science & Technology, Faculty of Fisheries & Marine Sciences, IPB University (Bogor Agricultural University), Campus IPB Dramaga, Bogor 16680, Indonesia
4 Environmental Research Center, IPB University (Bogor Agricultural University), IPB Dramaga Campus, Bogor 16680, Indonesia

*Corresponding author: zairion@apps.ipb.ac.id

Abstract. The blue swimming crab (*Portunus pelagicus* Linnaeus, 1758) inhabits coastal waters with sandy or muddy substrates of Southeast Asia. Aquatic environment and fishing intensity might influence the variation in morphometric characters of species as a form of adaptation and might characterize the stock unit as well. This study was aimed to analyze the morphometric variation of the blue swimming crab (BSC) population in western and eastern parts of Java Sea as part of Fisheries Management Area (FMA 712) of Indonesia. The representative crab samples for both males and females were taken randomly from three different locations, i.e. East Lampung, Rembang, and Southern Madura Island. Those samples were analyzed with a method called “conventional morphometric method”. Result of the Kruskal-Wallis test showed that 10 characters were significantly different between male and female crabs. The cluster analysis also showed that the crabs in East Lampung and Rembang had high similarities which tended to be close population, while Southern Madura’s crabs were seemed to be dissimilar. In addition, discriminant analyses also showed that the BSC population in Southern Madura was different from the other two populations, indicating that the BSC population of Southern Madura is a different stock unit.

1. Introduction

Marine biological resources in Indonesia can be used for food and industrial materials. One of the marine biological resources is blue swimming crab (*Portunus pelagicus*) which is an important economic fishery commodity with high demand and has a high price [1-2]. Crab exports are proven to provide a large foreign income contribution to Indonesia. In 2016, the Indonesian export volume of
combining mangrove crab and blue swimming crab meat reached 19,387 tons with the value of US $246 million. In 2017, the export volume reached only 15,867 tons, but a value increased to US $308 million [3].

The blue swimming crabs (BSC) is distributed in the coastal waters of East Asia and Southeast Asia [4], with sandy or muddy substrates at maximum 40 m depth, including estuary, lagoon, and sea grass ecosystems [5]. The adult BSC are found living on the bottom of the waters, whereas larval and megalopa stages move and are carried by currents and live as plankton [6]. Adult and juvenile BSC live in a bottom of coastal area and the female migrates to the deeper sea to spawn and return to estuary after spawning. Males and females migrate from estuary as a reaction to low salinity [7]. The differences in the characteristics of aquatic environments may influence of morphological character change in a species as its adaptation effort [8].

The BSC has a high potential in boosting economics with high prices. The high selling value may cause continuously catch by fishermen and trigger overfishing in BSC resources. Overfishing occurs due to lack of knowledge about the biological development phases and to some extent it was caused by a decrease in recruitment rates. These conditions make stock decreasing of BSC in nature [2]. Knowledge about resource conservation is important to establish a better fisheries management that is not only oriented towards production but also the condition of ecosystems. Records of catch production completely are still difficult to obtain. This phenomenon is caused by the unrecorded catches since mostly they are sold directly and exported. Small-scale fisheries activities and highly fluctuation production of BSC is believed to have a direct relationship with stock availability [9].

According to Regulation of the Minister of Maritime Affairs and Fisheries No. 18/PERMENKP/2014, management of BSC resources in the Fisheries Management Area (FMA) of the Republic of Indonesia is currently still based on the same production and ecosystem conditions. This management system can lead to a mistake in determining the status of any existing species. A study of stock identification is then needed to elucidate the stock structure based on stock fisheries management [10].

Morphometric characters can provide information on the differences in population groups that can also be used as a stock identifier. The intra-species morphological differences are clearly illustrated in overall body shape. In addition, morphometric characters are also used to express information related to sex, intra-species morphological diversity patterns, and to classify the kinship of two species or more [11].

Morphometric analysis of the BSC has been widely used to correlate gonad maturity and reproduction [1, 12-14]. The use of a morphometric analysis approach with the conventional method to reveal species variation from different locations is limited. This study was aimed to analyze the morphometric variation and elucidate the blue swimming crab (BSC) population in western and eastern part of Java Sea as representative of Fisheries Management Area (FMA 712) of the Republic of Indonesia.

2. Methodology

2.1. Research location
The research was conducted from May to August 2018 in three locations, i.e. East Lampung, Rembang, and South Madura in the western and eastern part of Java Sea as representative of Fisheries Management Area 712 of the Republic of Indonesia (Figure 1). The specimens were measured at Aquatic Molecular Biology Laboratory, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University.

2.2. Data collection
Specimens were collected from local fishermen in fish landing site with a simple random sampling method at the three locations. The number of samples was taken at each location around 73-105 individuals, ranging from the smallest to largest sizes with the number of male and female BSC samples not equal, depending on the sex proportion of caught crabs. The specimens were kept in cool
box and transported to the laboratory and were stored in frozen condition for next analysis. Measurement of the BSC sample was done by determining the sex, weighing, and morphometric characters using imageJ software.

Figure 1. Map of research location in western and eastern part of Java Sea as representative of Fisheries Management Area (FMA) 712 of Indonesia.

Figure 2. Morphometric characters of blue swimming crab (*Portunus pelagicus* Linnaeus, 1758) which were measured for conventional methods analyses (Adopted from Lai et al. [4] and Irmawati et al. [15]).
The sex was determined based on secondary sexual characteristics, while the weight was measured using a digital scale to nearest 0.1 gram. Before morphometric measurement, carapace of BSC was separated from other part of body. The carapace was then dried by tissue paper. The dried carapace was placed on the top of styrofoam with millimeter block, and then was marked with a pin as a landmark position for morphometric characters. The landmark point was made clear, consistent, and homologous for all specimens, and then the images were taken by a digital camera using a Canon EOS 1300D. The digital camera was equipped with a tripod to produce the same condition of distance, magnification, and light settings for each specimen. The resulting photograph would be measured the morphometric character using PAST software. The sketch of all morphometric characters was shown in Figure 2.

2.3. Data analysis

2.3.1. Carapace width-carapace length relationship. Analysis of allometric relationship was performed on carapace width and carapace length. The analysis was conducted with carapace width as the variable y (the dependent) and carapace length as the variable x (independent). Regression analysis was then made which was aimed to obtain the equation of the two characters. The differences in growth patterns could be determined by testing the value of slope (b) and intercept (a) using covariance analysis (ANCOVA).

Based on covariance analysis the difference in growth rate can be determined by using different slope values. The possible influence of location on the character was tested could by conducting an intercept test. The test was done when the interaction between locations with carapace length was not significantly different ($p>0.05$). If the value of the influence of the location obtained is significantly different ($p<0.05$), then it can be said that there is a difference in carapace width or internal carapace width at the same carapace length.

2.3.2. Morphometric character diversity

Analysis was carried out on several morphometric characters. The analysis was conducted with the Kruskal-Wallis test, discriminant analysis, and cluster analysis. The Kruskal-Wallis test was used to reveal significant differences of morphometric characters among the small crab groups in all sampling locations [16]. Discriminant analysis was conducted to determine population groupings based on different locations [8]. While cluster analysis was used to decide the similarity between groups formed based on morphometric characters.

3. Results

3.1. Carapace width and weight measurements

The total of BSC samples for both female and female were 277 individuals from the three sampling sites. The mean and standard deviation of carapace width and weight showed variation in the three locations (Table 1). The largest mean of carapace width and weight in males were found in Southern Madura, while the smallest were in Rembang. The largest mean of carapace width in females was found in Madura and the smallest was in Rembang, however the largest mean of weight of females was in East Lampung, and the smallest was in Southern Madura.

3.2. Carapace width-carapace length relationship

The relationship between CW-CL and ICW-CL of male and female BSC in all locations had significantly different slope values ($p<0.05$), indicating a non-parallel relationship (Table 2). The non-parallel relationship means that growth rate of carapace width (CW) or internal carapace width (ICW) to carapace length (CL) was difference.
Table 1. Mean, standard deviation of carapace width and weight of the blue swimming crab (*Portunus pelagicus*) collected from East Lampung, Rembang and Southern Madura.

| Location          | n  | Carapace Width (mm) |  | Weight (gram) |  |
|-------------------|----|---------------------|---|---------------|---|
|                   |    | Max     | Min     | Mean    | SD  | Max     | Min     | Mean    | SD  |
| Male              |    |          |         |         |     |          |         |         |     |
| East Lampung      | 59 | 147.03  | 86.28   | 118.09  | 13.31| 212.4   | 38.5    | 109.74  | 36.94|
| Rembang           | 24 | 134.58  | 94.58   | 107.97  | 10.35| 144.1   | 55.8    | 82.14   | 23.80|
| Southern Madura   | 82 | 154.04  | 71.13   | 119.54  | 13.98| 247.4   | 22.6    | 116.76  | 42.88|
| Female            |    |          |         |         |     |          |         |         |     |
| East Lampung      | 40 | 164.45  | 77.32   | 111.55  | 18.56| 311.4   | 29.5    | 93.49   | 63.20|
| Rembang           | 49 | 157.25  | 78.21   | 106.35  | 17.17| 277.6   | 33.7    | 85.58   | 52.34|
| Southern Madura   | 23 | 144.79  | 91.85   | 112.68  | 17.79| 182.3   | 34.4    | 83.67   | 42.54|

Note: n = number of samples, Max = Maximum, Min = Minimum, SD= standard deviation.

Table 2. The relationship between carapace width (CW) and internal carapace width (ICW) to carapace length (CL) of male and female blue swimming crab (*Portunus pelagicus*) in each location.

| Relationship/Sex/ Location | Equation (y = a + bx) | p   | R²  | b  | a   |
|---------------------------|-----------------------|-----|-----|----|-----|
| CW-CL relationship        |                       |     |     |    |     |
| Male                      |                       |     |     |    |     |
| East Lampung              | 6.9575 + 2.1402x      | 0.05| 0.9379 | Non-parallel | - |
| Rembang                   | 4.1405 + 2.1509x      | 0.05| 0.9234 | Non-parallel | - |
| East Lampung              | 6.9575 + 2.1402x      | 0.05| 0.9379 | Non-parallel | - |
| Southern Madura           | 14.1098 + 1.8058x     | 0.05| 0.9549 | Non-parallel | - |
| Rembang                   | 4.1405 + 2.1509x      | 0.05| 0.9234 | Non-parallel | - |
| Southern Madura           | 14.1098 + 1.8058x     | 0.05| 0.9549 | Non-parallel | - |
| Female                    |                       |     |     |    |     |
| East Lampung              | 16.4435 + 1.9320x     | 0.05| 0.9748 | Non-parallel | - |
| Rembang                   | 15.1056 + 1.9135x     | 0.05| 0.9820 | Non-parallel | - |
| East Lampung              | 16.4435 + 1.9320x     | 0.05| 0.9748 | Non-parallel | - |
| Southern Madura           | 14.7111 + 1.8042x     | 0.05| 0.9628 | Non-parallel | - |
| Rembang                   | 15.1056 + 1.9135x     | 0.05| 0.9820 | Non-parallel | - |
| Southern Madura           | 14.7111 + 1.8042x     | 0.05| 0.9628 | Non-parallel | - |

ICW-CL relationship

| Male                      |                       |     |     |    |     |
| East Lampung              | 3.2453 + 1.7197x      | 0.05| 0.9657 | Non-parallel | - |
| Rembang                   | 1.5653 + 1.7298x      | 0.05| 0.9633 | Non-parallel | - |
| East Lampung              | 3.2453 + 1.7197x      | 0.05| 0.9657 | Non-parallel | - |
| Southern Madura           | 6.2235 + 1.5782x      | 0.05| 0.9732 | Non-parallel | - |
| Rembang                   | 1.5653 + 1.7298x      | 0.05| 0.9633 | Non-parallel | - |
| Southern Madura           | 6.2235 + 1.5782x      | 0.05| 0.9732 | Non-parallel | - |
| Female                    |                       |     |     |    |     |
| East Lampung              | 2.3674 + 1.7447x      | 0.05| 0.9917 | Non-parallel | - |
| Southern Madura           | 4.4706 + 1.6773x      | 0.05| 0.9876 | Non-parallel | - |
| East Lampung              | 2.3674 + 1.7447x      | 0.05| 0.9917 | Non-parallel | - |
| Southern Madura           | 3.1223 + 1.6520x      | 0.05| 0.9825 | Non-parallel | - |
| Rembang                   | 4.4706 + 1.6773x      | 0.05| 0.9876 | Non-parallel | - |
| Southern Madura           | 3.1223 + 1.6520x      | 0.05| 0.9825 | Non-parallel | - |

Note: a = intercept, b = slope, p = p-value, R² = determination coefficient.
3.3. Variation of morphometric characters
The Kruskal-Wallis test showed the variation in morphometric characters of the BSC in all sampling locations, which was significantly different \((p < 0.05)\) in 10 characters for both males and females (Table 3 and Table 4). All characters were considered to influence the grouping of populations.

3.4. Population proximity grouping
The results of cluster analysis in male and females from three locations had the same pattern (Figure 3). The BSC of East Lampung (1) and Rembang (2) have high similarity and tend to have a close kinship, while the Southern Madura crab (3) tend to be different.

The BSC population proximity group in all sampling locations can also see based on the Euclidean distance value of cluster analysis. The greater Euclidean distance value indicated that the similarity between groups getting smaller, while the smaller distance value showed the similarity between groups getting bigger. The proximity value of the male and female BSC in East Lampung is more similar to the crab in Rembang compared to the BSC in Southern Madura (Table 5).

| Morphometric characters | Mean Ratio | df | p-value |
|-------------------------|------------|----|---------|
|                         | East Lampung | Rembang | Southern Madura |
| LPCL/CW | 0.4444 | 0.4294 | 0.4155 | 2 | 0.000 |
| LACL/CW | 0.4144 | 0.4028 | 0.4108 | 2 | 0.000 |
| LOW/CW | 0.0851 | 0.0916 | 0.1025 | 2 | 0.000 |
| FRMW/CW | 0.1850 | 0.1920 | 0.1617 | 2 | 0.000 |
| ROW/CW | 0.0862 | 0.0911 | 0.1036 | 2 | 0.000 |
| RACL/CW | 0.4036 | 0.4056 | 0.4106 | 2 | 0.000 |
| RPCL/CW | 0.4353 | 0.4236 | 0.4192 | 2 | 0.000 |
| PBW/CW | 0.2129 | 0.2523 | 0.2763 | 2 | 0.000 |
| ICW/CW | 0.7837 | 0.7880 | 0.8225 | 2 | 0.000 |
| CL/CW | 0.4397 | 0.4472 | 0.4879 | 2 | 0.000 |

| Morphometric characters | Mean Ratio | df | p-value |
|-------------------------|------------|----|---------|
|                         | East Lampung | Rembang | Southern Madura |
| LPCL/CW | 0.4486 | 0.4386 | 0.4198 | 2 | 0.000 |
| LACL/CW | 0.4104 | 0.4059 | 0.4058 | 2 | 0.018 |
| LOW/CW | 0.0846 | 0.0895 | 0.1003 | 2 | 0.000 |
| FRMW/CW | 0.1871 | 0.1909 | 0.1618 | 2 | 0.000 |
| ROW/CW | 0.0857 | 0.0911 | 0.1012 | 2 | 0.000 |
| RACL/CW | 0.4018 | 0.4030 | 0.4099 | 2 | 0.005 |
| RPCL/CW | 0.4392 | 0.4286 | 0.4319 | 2 | 0.001 |
| PBW/CW | 0.2064 | 0.2278 | 0.2604 | 2 | 0.000 |
| ICW/CW | 0.7864 | 0.7925 | 0.8221 | 2 | 0.000 |
| CL/CW | 0.4379 | 0.4471 | 0.4807 | 2 | 0.000 |
Figure 3. The result of cluster analysis of the blue swimming crab (*Portunus pelagicus*) morphometric characters in East Lampung, Rembang and Southern Madura: (A) male and (B) female.

Table 5. Euclidean distance of male and female blue swimming crab (*Portunus pelagicus*) morphometric characters in East Lampung, Rembang and Southern Madura.

| Sex/Location | Euclidean distance | East Lampung | Rembang | Southern Madura |
|--------------|--------------------|--------------|---------|-----------------|
| **Male**     |                    |              |         |                 |
| East Lampung | 0.000              | 0.045        | 0.169   |                 |
| Rembang      | 0.045              | 0.000        | 0.208   |                 |
| Southern Madura | 0.169         | 0.208        | 0.000   |                 |
| **Female**   |                    |              |         |                 |
| East Lampung | 0.000              | 0.030        | 0.096   |                 |
| Rembang      | 0.030              | 0.000        | 0.072   |                 |
| Southern Madura | 0.096          | 0.072        | 0.000   |                 |

Based on the discriminant analysis, morphometric character distribution plot of the BSC showed a clear grouping population (Figure 4). The BSC in Southern Madura (3) tend to be different population group compared to the BSC in East Lampung (1) and Rembang (2). Both male and female BSC sample from Southern Madura were not also mixed to the group prediction of the BSC from East Lampung and Rembang. There are two data of male BSC from Rembang being part of population group from East Lampung, and five data of female BSC from Rembang included in population group the BSC from East Lampung. In addition, nine data of female BSC from East Lampung was part of population group of the BSC from Rembang (Table 6).
Figure 4. Morphometric characters distribution plot of the blue swimming crab (*Portunus pelagicus*) in three locations: (a) male (b) female.

Table 6. Group prediction among male and female of the blue swimming crab (*Portunus pelagicus*) in three locations.

| Location         | East Lampung | Rembang | Southern Madura | Total |
|------------------|--------------|---------|-----------------|-------|
| Male             |              |         |                 |       |
| East Lampung     | 59           | 0       | 0               | 59    |
| Rembang          | 2            | 22      | 0               | 24    |
| Southern Madura  | 0            | 0       | 82              | 82    |
| Total            | 61           | 22      | 82              | 165   |

| Location         | East Lampung | Rembang | Southern Madura | Total |
|------------------|--------------|---------|-----------------|-------|
| Female           |              |         |                 |       |
| East Lampung     | 31           | 9       | 0               | 40    |
| Rembang          | 5            | 44      | 0               | 49    |
| Southern Madura  | 0            | 0       | 23              | 23    |
| Total            | 36           | 53      | 23              | 112   |

4. Discussion

Carapace width and weight of male crabs was greater than those of female crabs in all locations. It was suspected that growth was a condition of increasing the length and weight at a certain time with following the growth pattern of blue swimming crab. The growth could be affected by several aspects, such as food availability, habitat conditions, and other factors [17]. Changes in the value of an individual's growth might be caused by the shape, size of carapace width, and weight [18]. It means that the availability of food, habitat conditions, and other factors in three locations might be the factors behind the growth of BSC [17].

Analysis of carapace width (CW) or internal carapace width (ICW)-carapace length relationship using conventional methods showed a non-parallel relationship in the three locations. Non-parallel relationship means that there were differences in the growth rate of carapace width (CW) or internal carapace width (ICW) at the same carapace length in all locations. Different growth could occur in the pre-molt phase of female crab living in a limit food availability environment [19, 20]. As a consequence the energy from their food could not be fully used for growth. Some other factors such as sex, temperature, and water salinity may also influence the growth of BSC [20, 21].

There were differences in morphometric characteristics of male and female blue swimming crabs compared between locations from different regions. The differences in morphological characters have been widely used to detect a possible different population of a species from the same or different area. Sex, classification of kinship relationships, and patterns of morphological diversity within the same species could also be determined based on morphometric characters. However, it should bear in mind
that the difference in morphometric characters could be influenced by the environmental condition. It has also been proved that environmental factors could affect the growth rate of a particular body part [22].

Discriminant analysis showed significant differences in the three locations. The form of BSC group was caused by habitat variances. Environmental conditions could affect the formation of population groups from different habitat [23]. This difference was thought to be due to adaptation process of BSC living in the different habitat with variation in environmental parameters. In addition, the grouping was probably influenced as well by the fairly large crab distribution since environmental factors such as temperature and salinity may affect the blue swimming crab distribution. Swimming crabs were reported to migrate into deep waters during the rainy season [24]. The wide distribution and relatively long-distance movements indicated that BSC was able to live in a high variation of environment.

Discriminant analysis showed that the geographical distribution area of BSC was known to be quite large. The large area is indicated by the existence of Lampung group near Rembang centroids and vice versa. Actually, the spread of BSC could be influenced by its life cycle. Small crabs had a life cycle that started from eggs, zoea, megalopa, juveniles, to adult crabs [25]. During planktonic stage, it is possible for BSC larvae to move further away from the area where they hatched. The BSC could move up to 80 km at sea in the larval phase before settling in shallow water [26]. Shallow waters were the place for juvenile phase [20, 25]. The juvenile to adult crab inhabited the estuary, the shallow coast and also the deeper sea. Their life cycle and habitat preferences may affect the population structure. In Bardawil lagoon Northern Sinai, Egypt BSC was found in intertidal areas with depths less than 1 m to river mouths or estuaries with depths of 60 m [27].

The cluster analysis from three locations showed that the BSC in East Lampung with Rembang had a greater similarity than Southern Madura. Such a cluster indicated that there were differences in morphometric characteristics between males and females in East Lampung and Rembang with BSC in Southern Madura. As discussed above different characteristics of aquatic environments could be a factor in changing the morphological character of a species as a form of organism adaptation [8]. With the assumption that environmental characteristics of East Lampung and Rembang were not the same with those of Southern Madura.

In terms of fishery management, there should be a different strategy to manage BSC resources in East Lampung and Rembang population compared to them in Southern Madura because it has been proved that there were two possible stocks in the three study sites. The result also proved that morphometric character analysis can be a strong complement in supporting identification of genetic and environmental stocks [28]. In other words, morphometric analysis of BSC character could be used as the basis for BSC management.

5. Conclusion
Males and females blue swimming crab (P. pelagicus) from the Southern Madura has several different morphometric characters with population from East Lampung and Rembang. This difference in morphological characters has shown that there was a different stock unit in Java Sea as FMA 712. The information is needed for developing the best management strategy in the exploitation of each unit stock.

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