Biomorphometry of coconut crabs (*Birgus latro*) in Laigoma Island, North Maluku, Indonesia

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Abstract. Coconut crab is a coastal animal that lives in coastal forests on islands of tropical Indo-Pacific. Crab populations are currently under threat of extinction. Several issues contribute to this, including high levels of exploitation, degradation of their native habitat, land clearance, and plantations development. This study aimed to examine the biomorphometric of coconut crabs, which includes the composition, sex ratio, distribution, width and weight relation, condition factors and gonad maturity level. The descriptive explorative methods was used in this research. The results showed that the composition of 156 coconut crabs consisted of 82 females. The results obtained a balanced sex ratio. The size of the carapace width obtained ranged from 40.15 to 88.55 mm, with a weight of 150-565 grams. The relationship between width and capacity is allometric. The values obtained from these factors ranged from 1.01 to 1.03 for men and 1.01 to 1.012 for females. The gonad maturity level of male and female mud crabs was dominated by TKG III and IV. This indicated that the research time was in spawning period.

1. Introduction

Coconut crab is a coastal animal that lives in coastal forests of islands of tropical Indo-Pacific. The crab populations are currently under threat of extinction. Several issues contribute to this, including high levels of exploitation, degradation of their native habitat, residential land clearance, and plantations [1].

Problems arise when coconut crab was widely hunted and captured, the coconut crab population declining in nature. Several previous studies in other areas have resulted in government policy and exploitation regulation of this resource, among others were in Vanuatu Islands, in national park of Christmas Island since 1978, but *B. latro* exploitation at outside the national park was still permitted under Environment Protection and Biodiversity Conservation Regulations [2].

The coconut crab is also a fishery resource that has high economic value. Use of coconut crab meat in some areas is not only for local (subsistent) consumption, but is also to be sold to restaurants at high prices. Increase in market demand resulted in crab overfishing and no longer paying attention to...
capturable size of the coconut crab. The Government of Indonesia, through the Decree of Minister of Marine and Fisheries No. 1/2015, imposes a ban to catch any crabs in conditions of laying eggs and with carapace width less than 15 cm.

Based on previous argumentation, it is necessary to collect data on number of coconut crab catches in several areas in North Maluku. Purpose of this study was to investigate bio-morphometrics of coconut crabs at research location that included size of coconut crab’s carapace width, relationship between carapace width and weight, sex ratio, condition factors, and gonad maturity level.

2. Materials and methods
The study was carried out on Laigoma Island, Kayoa District, South Halmahera Regency, North Maluku. Research location is at 0° 8’ 20.68962”N and 127° 12’ 58.93066”E. This research is conducted from January to March 2020. Research location consisted of 3 stations, namely Pasir Besar (Station 1) and Pasir Kecil (Station 2) that represent characteristics of beach with a rather steep cliff, and Sumber Air (Station 3) representing characteristics of beach having combination of quite steep cliff and slightly sloping sandy beach.

2.1 Collecting data
Most common method of local fishers to catch coconut crabs is by hand using coconut bait. Baiting is carried out during the day. Catching coconut crabs is usually done at night, starting from 8PM to 1AM past midnight. At each station, a 10 x 10 m transect was installed. Each station has as many as 6 coconuts. Captured coconut crab samples were collected for measurement of thoracic length (TL) and Carapace width. Then they were weighed digitally using a scale with an accuracy of 1 gram. Sex was determined by form of the crab’s abdomen, since male crabs do not have pleopod and while female crabs have one. Egg maturity was measured morphologically and then they were classified into five stages of gonad maturity level [3].

2.2 Frequency Distribution analysis carapace width and weight
Descriptive statistical data analysis carried out included to find and describe frequency distribution of carapace width and weight of coconut crabs, class intervals, mean value, and frequency. Data processing and statistical calculation and basic analysis was carried out with Microsoft Excel 2010 program.

![Figure 1. Dorsal (A) and lateral (B) views of Birgus latro illustrating the various measurements. (figure modified from Fletcher and Amos 1994) [4], [5]](image)

2.3 Analysis of sex ratio
The sex ratio is the share of males and females in a population. This male to female ratio can be calculated using the following formula [6]
Where $P = \text{Sex ratio between male and female crabs}$, $A = \text{Number of male crabs}$, $B = \text{Number of female crabs}$.

Furthermore, the sex ratio was tested using Chi-Square with the formula: The relationship between males and females in a population can be determined by analysing the sex ratio of coconut crab using the Chi-square test ($X^2$) [7], [8]:

$$X^2 = \sum \frac{(o_i-e_i)^2}{e_i}$$

Where $X = \text{value for a random variable X}$ whose sample distribution is close to the Chi-square distribution, $O_i = \text{observed frequency of male and female coconut crabs}$, $E_i = \text{expected frequency of male and female coconut crab divided by two}$.

2.4. Analysis of the correlation between carapace width and weight

Analysis of the relationship between carapace width and weight can be used to study growth patterns. The relationship between carapace width and weight based on [6] can be determined by the formula:

$$W = a L^b$$

Where $W = \text{Weight (g)}$, $L = \text{Width (mm)}$, $A = \text{Intercept (intercept of the width-weight relationship curve with the y-axis)}$, $B = \text{Estimator of growth pattern width and weight}$.

2.5 Condition factor analysis.

Condition factor shows good or bad condition of a biota in terms of its physical capacity. From a commercial point of view, this condition means quality and quantity of availability [9]. To calculate the condition factor, growth pattern of the biota must be first known.

a. If the growth of the coconut crab is isometric (b=3), then the equation used is:

$$Kn = 100 \times \left(\frac{W}{L^3}\right)$$

b. If the growth of the coconut crab is allometric (b≠3), then the equation used is:

$$Kn = \frac{W}{a L^b}$$

Where $Kn = \text{Coconut crab condition factor}$, $W = \text{Weight (g)}$, $L = \text{Width (mm)}$, $A = \text{Intercept (intercept of the width-weight relationship curve with the y-axis)}$, $B = \text{Estimator of growth pattern width and weight}$.

3. Result and discussion

Study results showed that the total number of coconut crabs caught was 156, consisting of 82 male crabs and 74 female crabs. Data of frequency distribution of carapace width and weight is presented in Figures 2 and 3.

Data in Table 1 shows that the highest yields of coconut crabs were located at station Pasir Besar (Station 1) with total catch of 70 crabs consisting of 38 male and 32 female crabs. While at station Pasir Kecil (Station 2), total crab sample caught was 54 crabs consisting of 28 male and 26 female coconut crabs. The lowest number of catch was at station Sumber Air (Station 3) with total of 32 crabs consisting of 16 male and 16 female crabs. The high and low number of coconut crabs obtained were thought to have relationship with uncontrolled catch activities by local fishers, resulting in a decrease
in the number. The high and low abundance of an organism is influenced by various factors, including physical and chemical factors of the water, which include temperature, salinity, current, pH, water depth, and basic substrate [10].

Table 1 Number of female and male coconut crabs captured on Laigoma Island (station 1, station 2 and station 3) during the study period.

| Location          | Male | Female | Total Number (tail) |
|-------------------|------|--------|---------------------|
| Station 1 (Pasir besar) | 38   | 32     | 70                  |
| Station 2 (Pasir kecil)  | 28   | 26     | 54                  |
| Station 3 (Sumber Air)    | 16   | 16     | 32                  |
| Total Number (Ind)       | 82   | 74     | 156                 |

Figure 2. Frequency Distribution of Carapace Width Classes of male and female coconut crabs caught on Laigoma Island. (a) Station 1 (Pasir Besar); (b) Station 2 (Pasir Kecil); and (c) Station 3 (Sumber Air).

The relationship between coconut crab populations during the study with habitat conditions, both terrestrial habitats, vegetation conditions, and soil texture. It can be seen that station 3 has the lowest number compared to stations 1 and 2. This is because station 3 is a location that is very close to
settlements, compared to stations 1 and 2, with the most optimal stations providing opportunities for coconut crab life, both at this stage of planktonic in the waters as well as when it becomes an adult coconut crab. At the research location on the island of Laigoma, coconut crabs were found in coastal areas that were still overgrown with primary vegetation. The condition of intact coastal forests can provide a direct source of food for nature. Conditions of trees that are still dense or lush create conditions of relatively high humidity. *Birgus latro* is the most preferred animal for fruits. The preferred types of fruits include coconut (*Cocos nucifera*), walnuts (*Canarium commune*), papaya (*Carica papaya*), banana (*Musa spp*), ketapang (*Terminalia catappa*), and pandan (*Pandanus spp*) [11]. Coconut crab is an all-consuming animal. Besides eating coconut meat, fruit pandanus, carrion, lobster, crab and shellfish.

According to this research, coconut crabs like dark, wet environments. This finding supports the coconut crab's activity pattern as a nocturnal species (active at night). However, on an area that is not much human disturbance, moist and protected, coconut crab can also be diurnal. On Pasoso Island, coconut crabs are naturally active at night (nocturnal). It is suspected that this is related to the existence of predators. The predator of this crab is the forest monitor lizard. The coconut crab that is in holes in the ground or rotting wood can anticipate predators [11]. Matter The same thing that was also found on Laigoma Island was coconut crabs doing activities at night.

![Graph A. Station 1 (Pasir Besar)](image1)

![Graph B. Station 2 (Pasir Kecil)](image2)

![Graph C. Station 3 (Sumber Air)](image3)

**Figure 3.** Frequency distribution of male and female coconut crab weights. Catch on Laigoma Island. Notes: (a) Station 1 (Pasir Besar) (b) Station 2 (Pasir Kecil) and (c) Station 3 (Source of Water).
The results of the measurement of the carapace width and weight of coconut crabs obtained 8 size classes at station 1 and station 2 locations, while station 3 locations obtained 7 size classes, as shown in Figure 2. The varying size of carapace width and weight is thought to be influenced by fishing time. It is associated with the coconut crab reproduction process, which lasts throughout the year and peaks in the rainy season. The results obtained are smaller than the size set by the government in Permen-KP No.1 of 2015, which states that the minimum size of the carapace width of crabs that can be caught is 15 cm. It can be concluded that the mangrove crabs caught during the study were young crabs and it is feared they have not entered the spawning season or have not had time to do recruitment.

According to Figure 3, the weight frequency of coconut crabs is split into 6 classes with a weight range of 150-565 grams, dominated by crab weight at station 1, weighing from 220-475 grams, and size at station 2, weighing from 220-385 grams. At Station 3, there are 5 classes with a crab size frequency dominated by 220-300 grams. The relationship is with the management of renewable and sustainable natural resources in maintaining the number of heavy coconut crab populations set by the government to be caught at a minimum weight of 200 g.

3.1 Sex ratio

The results of the sex ratio comparison or sex ratio of coconut crabs on Laigoma Island showed that at station 1 they obtained 38 male crabs and 32 male crabs, with a ratio of 1:1.06. While coconut crabs at station 2 produced 28 male crabs and 26 female crabs. Female with a ratio of 1:1.04, and station obtained 16 male crabs and 16 female crabs with a ratio of 1:1. Figure 4 depicts the results of a comparison of sex ratios or sex ratios of coconut crabs on Laigoma Island.

During the study, 82 male and 74 female crabs with a sex ratio of 1:1 got a Chi-Square test result of 1:1 at a significance level of 0.05. It was discovered that the sex ratio was balanced. In a population, if the sex ratio is not balanced, then the development of the population is hampered. The balance of male and female sex ratios can result in disruption of crab development until the recruitment phase, so that population declines can occur. The cause of this imbalance is thought to be due to the influence of behaviour, spawning season, size of first gonad maturity and growth. It is important to know the sex ratio because it affects the stability of the crab species population [12].

The sex ratio is an indicator of the population in an area that can predict whether the population is good or not. A good population is supported by an ideal habitat for the survival of the population. In good habitats, the population is usually balanced. In the study on Laigoma Island, it was found that the sex ratio value was still balanced because it was supported by ideal habitat conditions.

![Figure 4. Sex ratio male and female coconut crab](image-url)
3.2 Correlation between carapace width and weight of coconut crabs on growth patterns

The relationship between the carapace width and weight of coconut crabs on growth patterns in this study can be seen in Table 2.

| Location | sex   | \( W = aL^b \) | \( R \) | \( R^2 \) | growth pattern   |
|----------|-------|----------------|-------|---------|-----------------|
| Station 1 | Female | 1.29L^{1.03} | 0.957 | 0.916   | Allometric Negative |
|          | Male   | 0.195L^{1.041} | 0.928 | 0.861   | Allometric Positive |
| Station 2 | Female | 1.501L^{2.001} | 0.861 | 0.741   | Allometric Negative |
|          | Male   | 0.469L^{2.646} | 0.85  | 0.722   | Allometric Positive |
| Station 3 | Female | 1.301L^{2.001} | 0.761 | 0.641   | Allometric Negative |
|          | Male   | 0.369L^{2.646} | 0.75  | 0.622   | Allometric Positive |

The results of the study in Table 2 where the value of b in the three research locations shows that the female crab is allometric is negative and the male crab is allometric is positive. According to regression analysis, the association between carapace width and coconut crab weight is substantial.

Based on Table 2, the b value of male coconut crabs is greater than that of female crabs. Differences in growth between females and males can be caused by differences in energy use. The energy consumed by male crabs is used to lengthen and enlarge the chelae (claws), which play a role in the mating process, while the growth of female coconut crabs tends towards the width of the carapace, because female crabs will moult every time they reproduce. The value of b in female crabs in the three locations was dominated by a negative allometric growth pattern. The growth of carapace width was faster than body weight. That female crabs have a negative allometric growth pattern due to more food intake used for moulting and the gonad maturation process (laying eggs) [13].

The allometric growth pattern is an unbalanced increase in length and weight. Coconut crabs, like other crustaceans, must do moulting or moulting activities. After moulting, the coconut crab will eat the exuvium from its shell. If the coconut crab does not eat exuvium from its shell, then the new shell does not reach the same degree of hardness as the previous shell. Furthermore, it is said that generally, what is eaten first is the thin chest. Claw is the last part eaten. Only a small part of the shell remains when the crab emerges from its hiding hole. Large coconut crabs take about three to four weeks to harden their cephalothorax. Determining the growth rate in coconut crabs, as in other crustaceans, is difficult because the exoskeleton will not reach the same degree of hardness as the previous shell. Furthermore, it is said that generally, what is eaten first is the thin chest. Claw is the last part eaten. Only a small part of the shell remains when the crab emerges from its hiding hole. Large coconut crabs take about three to four weeks to harden their cephalothorax. Determining the growth rate in coconut crabs, as in other crustaceans, is difficult because the exoskeleton will be lost when moulting occurs. Therefore, an appropriate marking method is needed so that even if moulting occurs, the given mark is not lost. *Birgus latro* has a slow growth rate [14].

3.3 Factor condition

The condition factor value of coconut crabs (*Birgus latro*) fluctuated over months and stations, both male and female crabs. During research, the average value of the male crab was 1.00-1.05 and the condition factor of the female crab was 1.01-1.16. The condition factor of male crabs at the station has an average value of 1.00-1.03 and the condition factor of female crabs is 1.00-1.012. An increase in the condition factor is an indication of an increase in reproductive activity, so it is estimated that the peak of the condition factor is the peak of spawning activity or the spawning season. Condition factors are essential growth derivatives. These condition parameters suggest that the crab is in good physical condition for survival and reproduction [11].

Theoretically, the value of the condition factor is directly proportional to body weight. If there is a decrease in environmental quality, the body weight will decrease as well. Variations in the value of condition factors depend on the availability of food, age, sex, and gonad maturity [11].

During the study, the average value of the condition factor for male crabs was 1.00-1.05 and the condition factor for female crabs was 1.01-1.16. The condition factor of male crabs at each station has an average value of 1.00-1.03 and the condition factor of female crabs is 1.00-1.012. Meanwhile, based on the statement [15] on Pasoso Island, there is a condition factor in male crabs having the
largest value of 1.15 and females reaching the highest value of 1.134. The peak of the curve can be interpreted as the readiness of coconut crabs to reproduce due to an increase in condition factors.

3.4 Gonad maturity level
Based on the results of observations of the level of gonad maturity during the study period from January to March, it was at TKG II and TKG III, with the size of the first TKG III gonad maturity found in the 50-59 mm class interval. The size of the coconut crab at the first time of gonad maturity is very important information because it is one way to determine the development of the coconut crab population. The first time the gonadal mature coconut crab is an indicator of the availability of reproductive stocks and is also important information in the application of fishing.

The Gonad maturity level (TKG) can be used as an estimate of the reproductive status of coconut crabs, age and first gonad maturity, and the proportion of productively mature stock with an understanding of the reproductive cycle for a population or species. In the reproductive process, before spawning occurs, most of the body’s metabolic products are intended for gonadal development [12].

The level of gonad maturity is the level or stage of gonad development before the egg is released or spawned. Gonads get heavier followed by an increase in size, including the size of the diameter of the egg in the ovary. Ovarian weight will reach a maximum as soon as the coconut crabs spawn, which will then decrease rapidly during spawning until the completion of spawning. Coconut crabs will reach gonad maturity when they reach the age of 3.5 to 5 years. At that age, the coconut crab will resume mating activities and restart its life cycle by releasing its eggs into the sea [16], [17], [18].

4. Conclusion
The conclusion of bio morphometric research on coconut crabs on Laigoma Island reveals that the sex ratio is balanced and that female and male crab development patterns are allometrically negative and positive. TKG III and IV dominate the gonadal level of the coconut crab, with January being the height of the rainy season and the transition of the season.

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