Morphometric characteristics of coconut crabs (*Birgus latro* Linnaeus, 1767) in North Moluccas Province, Indonesia

[1,2]Rugaya Serosero, [3]Sulistiono, [3]Nurlisa A. Butet, [3]Etty Riani

[1] Study Program of Aquatic Resources Management, Faculty of Fisheries and Marine Science, Khairun University, Ternate, North Moluccas, Indonesia; [2] Aquatic Resources Management Program, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Bogor, West Java, Indonesia; [3] Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Bogor, West Java, Indonesia. Corresponding author: R. Serosero, rugayaserosero@yahoo.co.id

Abstract. Coconut crab (*Birgus latro*) is a fishery resource of crustacean class that lives on land with the largest size up to 4 kg. This research was conducted to reveal morphometric characteristics of the coconut crabs populations living in Daeo (Morotai Island), Laigoma (South Halmahera District) and Fitako (North Halmahera District), of North Moluccas Province. The morphometric characteristics measured included the claw length i.e. the ductyl length (DacL), propodus length (PL), carpus length (CL), and merus length (ML) on the first to the fourth walking leg on the left and right claws and carapace characters consisting of chest length, cephalotorax length with rostrum, cephalotorax length without rostrum and head length as well as body weight. The data analysis was conducted using SPSS program version 16 and Minitab version 18. The results showed that the average left claw characters have sizes larger than the right ones. The compared characters were not significantly different within or among the populations ($p > 0.05$) except for the character of propodus length of the fourth walking leg in Daeo population but significantly different in Fitako population ($p < 0.05$). However, the character cannot become the characteristic of the population phenotype because based on the cluster analysis, all characters of the males and females of coconut crabs are mixed together and based on the discriminant analysis, there is an occurrence of the sharing component of the morphometric character values compared.
Key Words: coconut crabs, *Birgus latro*, Daeo, Fitako, Laigoma, morphometric.

Introduction. Robber crab or coconut crab (*Birgus latro* Linnaeus, 1767) belongs to the family Coenobitidae, infraorder Anomura. Coconut crabs are one of the fishery resources of the crustacean class living on land with the largest size up to 4 kg (Brown & Fielder 1991; Hamasaki et al 2011). Coconut crabs are a typical group of hermit crabs that does not carry the shell of gastropods throughout their early stages of life (Helfman 1977). In their life cycle, the female coconut crabs will incubate their eggs in the coastal areas and the larvae are planktonic (Schiller et al 1991). The larvae will pass through the 4-5 zoea stage at sea before their metamorphosis reaches the benthic megalopa stage and utilize the gastropod shells to migrate to the shoreline (Reese & Kinzie 1968; Brown & Fielder 1991; Wang et al 2007). The use of gastropod shells in this phase of glautochea is a behavioral adaptation that demonstrates the successful emigration of coconut crabs from waters to the mainland, and it is a way to protect themselves from drought and predators.

Coconut crabs are used as food in some restaurants in the Indo Pacific because of their delicious meat (Amesbury 1980; Kessler 2006; Buden 2012). Coconut crabs population has decreased in the inhabited areas because of their human predators (Whitten et al 2002) as well as their habitat degradation for various needs. The coconut crabs have been listed on the IUCN as a red list since 1981 but their status was changed to a data deficit in 1996 (Eldredge 1996). In Indonesia through the Minister of Forestry

Regulation No. P.57/Menhut-II/2008 on the strategic direction of conservation of national species from 2008 to 2018, the status of coconut crabs is as a protected animal and is not included in IUCN scarcity list because it is categorized as deficient data (Permenhut 2008).

The morphology of anomourous crabs such as *Birgus* was evolved from the descendants of the hermit crab (Barnes 1974). The coconut crab is made up of a front part called the cephalothorax (head-chest), has 5 pairs of legs i.e. the pair of front legs (pereopod I) containing large chelaes used to open coconuts or other foods (Burggren & McMahon 1988; Drew et al 2010) and smaller claws serving to move food to maxillipeds (Burggren & McMahon 1988). Two other pairs of legs (pereopods II and III) are used for walking and allowing coconut crabs to climb trees. The fourth pair of legs (pereopod IV) are smaller with a claw at the end which allows the coconut crabs to hold the inside part of the shell or coconut shell and carry it. The very small fifth pair (pereopod V) serves to cleanse the respiratory organs and be hidden under the carapace. Pleopoda II to IV are located on the left side of the abdomen and only owned by female coconut crabs, and they serve to carry eggs (Brown & Fielder 1991). The back part of the coconut crabs is called the abdomen and the telson covered by exoskeletons. The other body parts include the antennae and the eyes (Barnes 1974; Motoh & Kuronuma 1980).

Coconut crabs are strong and utilize their claws to clamp if they become disturbed. They also often exhibit aggressive behavior when dealing with humans and exhibit agonistic behavior of attack or escape behavior. This condition is common when coconut crabs are in the group even though they are solitary (Helfman 1977). Generally, coconut crabs with smaller sizes tend to lose a fight with those with larger sizes (Helfman 1977; Amesbury 1980). In populations in nature, there is often competition between species to food and space (habitat). Lee (1995) states that the claws on decapoda have multifunctions, i.e. for feeding, agonistic interaction and male competition to capture females. The structure and size of cheliped on crustacean decapods are influenced by different selection pressures and phylogenetic development. In its life cycle, the abdomen of coconut crabs undergoes a transition from symmetry in the phase of the zoeae to asymmetry in the early glutochea and juvenile phases and returns close to symmetry when it lives freely in phase after juvenile and adult except for pleopods in females (Burggren & McMahon 1988); however, the asymmetrical form of chelae remains the same until adulthood on male and female coconut crabs.

Growth causes a change in coconut crab size to the weight and length of its segments. Growth is influenced by food availability (Drew et al 2010), habitat and environmental suitability and availability of resources (Hartnoll 2001). The large size of coconut crab is useful as a physical protector of various predators. Sato et al (2010), based on their laboratory trials found that large male coconut crabs are preferable by females as their partner, and large males can be useful in sperm production for reproduction. Fierce competition from females causes male crabs to prepare greater energy for growth and for reproduction and to compete with other males (Baeza & Thiel 2007).

Research on the morphometric characteristics of coconut crabs is still rarely conducted, especially in North Maluku Province in three districts, namely, Daeo (Morotai Island), Laigoma (Halmahera Selatan Regency) and Fitako (North Halmahera Regency) which are potential areas of coconut crabs. This research was conducted to reveal the morphometric characteristics of coconut crabs in these three locations as initial information on the sizes of coconut crabs in North Moluccas.

Meterial and Method

Sampling location. Coconut crab samples were obtained from three locations, Fitako of North Halmahera Regency, Laigoma of South Halmahera Regency and Daeo Regency of Morotai Island (Figure 1). The location of Daeo Regency of Morotai Island is divided into three stations, namely, Station I adjacent to the settlement, Station II steep area with varied coastal vegetation, and Station III shallow areas located on flat areas and composed of various vegetation and coconut trees.

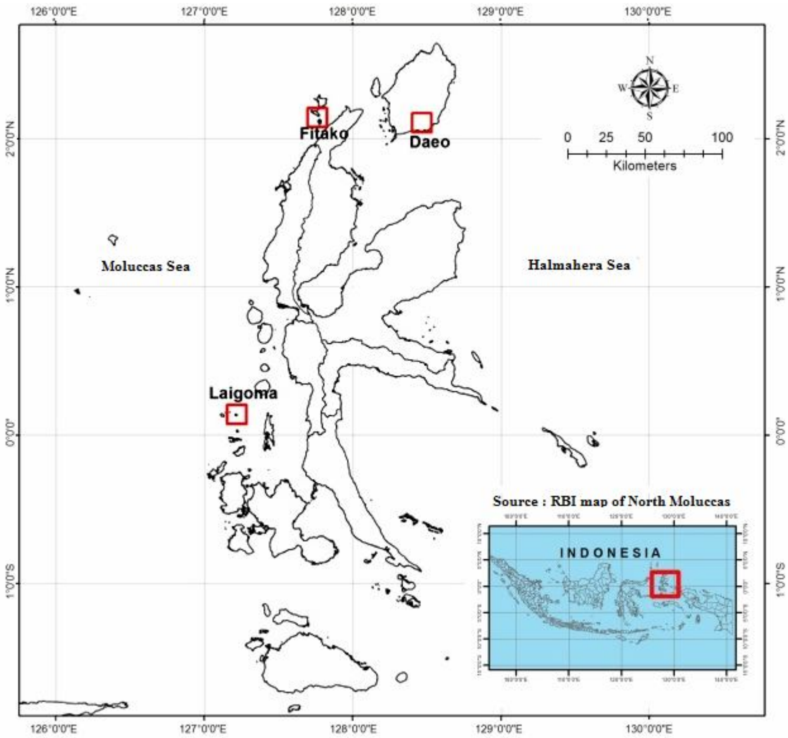

Figure 1. Sampling locations of coconut crabs.

Sample collections. *B. latro* were obtained from the catches in the three research sites i.e. Daeo (Morotai Island), Fitako (North Halmahera) and Laigoma (South Halmahera). The Fitako and Laigoma sites consisted of only one station with the number of samples used by each was 31 individuals from the Fitako population and 24 individuals from the Laigoma population. The number of samples in Daeo location was based on the amount of catches for one year. The coconut crabs caught were weighed using a digital hanging scale (0.01 g accuracy), and the morphometric character measurement was performed with a digital caliper (0.01 mm precision) (Figure 2). The morphometric character measurement was based on Fletcher et al (1989), and Anagnostou & Schubart (2014).

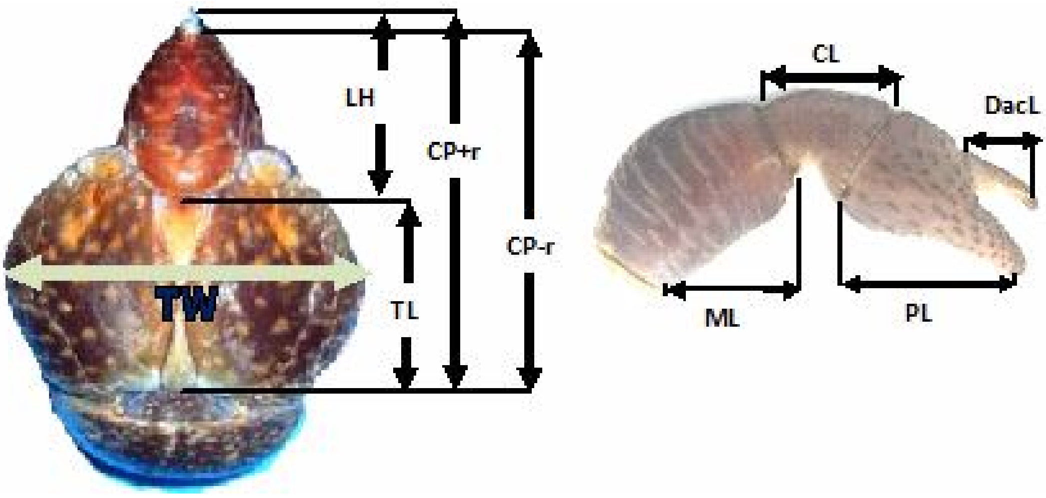

Figure 2. Morphometric characters of *B. latro*: DacL= dactilus length, PL = propodus length, CL = carpus length, ML = merus length, TW = thorax width, TL = thorax length, HL = head length, Cp+r = chepalotorax length plus rostrum, and Cp-r = chepalotorax length minus rostrum.

Data analysis. The distribution of the morphometric sizes was displayed with average sizes and standard deviation. The morphometric character test was performed by the non-parametric statistical test with SPSS program of version 16. The heterochely male and female characters were depicted by asymmetric index (AI) (Van Valen 1962 in Anagnostou & Schubart 2014) with the following formula:

$$AI= \frac{(R^* - L^*)}{(R^* + L^*)}$$

where R* and L* are the standarised values of the measurable parameters of right cheliped (R) and left cheliped (L).

The AI value is between -1 and +1. If AI is 0, it indicates there is no difference in size between the right and left cheliped parameters (perfect homochely). If AI is < 0, it indicates that the left cheliped parameter is larger than the right one (heterochely). If AI is > 0, it indicates that the left cheliped parameter is smaller than the right one (heterochely). The difference in media values between male and female AI was tested by Mann Whitney test.

Coefficient diversity. The values of the diversity coefficient were calculated from the morphometric character data (DacL, PL, CL, ML) of the first to the fourth walking leg of the left and right claws and TW, HL and CP-r that had been in ratio with TL. Chest length is most commonly used compared to carapace length, cephalotorax length with rostrum and chest width as these parameters are least susceptible to measurement variation due to damage on the coconut crabs body parts (Amesbury 1980). The ratio performed to one morphometric character that is not susceptible to changes aims to avoid differences in morphometric characters caused by different age structures. The diversity coefficient is used to determine the diversity of each morphometric character in each population by the following formula (Walpole 1992):

$$CD= \frac{SD}{\bar{X}} x\ 100\%$$

where CD is the diversity coefficient, SD = standard deviation and $\bar{X}$ is the average value.

The comparison of morphometric ratio data among the regions was conducted using Multivariate Analysis of Variance (MANOVA) of one way test followed by the smallest real difference test at the α level of 0.05 level using SPSS version 16.

Cluster analysis. The cluster analysis was conducted based on the coconut crab morphometric data from all locations. The distance matrix used as the basis for dendrogram construction was the distance of Mahalanobis. This distance was calculated with the help of Minitab 18 software. Subsequently, dendrogram was constructed according to the matrix distance using the UPGMA (Unweighted Pair Group Method with Arithmetic Mean) MEGA 5.0 software (Tamura et al 2011) as directed by Kumar et al (1993). Cluster analysis was used to see genetic relationship and the degree of similarity of each population based on morphometric characteristics measured.

Discriminant analysis. Discriminant analysis was performed to classify data based on the quantitative variables. This analysis was conducted to determine the grouping of the coconut crab based on its morphometric characters measured. Through this analysis, the percentage of sharing component values that occurred due to morphometric similarities among regions, causing the occurrence of grouping errors was obtained. The discriminant analysis was performed based on stepwise method using SPSS 16 software. The distribution of coconut crabs populations was based on their morphometric characters using the discriminant canonical analysis of PCA with the help of Minitab 18 software.

The relationship of morphometric characters. The correlation of morfometric characters measured was chest length (CL) with DacL, PL, CL, and ML on left and right claws for male and female using equations by Ricker (1975), Effendie (1979), and Anagnostou & Schubart (2014): $Y = aX^b$, where Y is the dependent variable (DacL, PL, CL, and ML) and X is the independent variable (TL). The linear relationships of TL with DacL, PL, CL, and ML were determined by transforming those parameters to logarithmic form, so logaritm equation ($\log Y = \log a + b \log X$) was obtained. The b value was tested to determine the growth pattern using t test, with the hypothesis: H0:b = 1, meaning length and weight relationship was isometric (balanced) and H1:b ≠ 1, meaning length and weight relationship was allometric (unbalanced) consisting of positive allometric and negative allometric. Positive allometric if the value of b > 1, i.e the increase in length was not as fast as the weight and negative allometric if the value of b < 1, i.e the increase in weight is not as fast as the length (Effendie 1979; Anagnostou & Schubart 2014). Decision determination: if the value of $t_{count} > t_{table}$, then reject the null hypothesis (H_0) and if the value of $t_{count} < t_{table}$, then accept the null hypothesis (H_0).

Results

Body size based on the morphometric characters. The body sizes of coconut crabs based on the 16 claw characters (DacL-1, PL-1, CL-1, ML-1, DacL-2, PL-2, CL-2, ML-2, DacL-3, PL-3, CL-3, ML-3, DacL-4, PL-4, CL-4, ML-4) on each left and right claws and the 5 characters on the carapace (TL, TW, HL, Cp+r, Cp-r) show that the male coconut crabs have a larger average size than the female ones, and their left claws are larger than the right ones on average (Table 1).

Table 1

Sizes of coconut crabs morphometric characters (mean and standard deviation) in Daeo, Fitako and Laigoma

Character	*Daeo (mm)*		*Fitako (mm)*		*Laigoma (mm)*	
	Male	*Female*	*Male*	*Female*	*Male*	*Female*
			Left cheliped			
DacL-1	30.87±5.81	26.39±4.76	27.34±3.68	27.52±3.40	27.20±2.70	27.73±2.87
PL-1	66.81±28.18	43.77±7.05	45.80±6.07	45.25±5.59	45.07±4.19	45.28±2.29
CL-1	30.96±6.17	27.14±5.47	28.27±4.23	28.21±4.90	28.05±3.99	28.19±5.85
ML-1	43.34±7.48	37.74±5.98	40.73±4.78	38.21±5.47	39.87±4.86	38.09±5.74
DacL-2	43.01±7.25	37.32±6.12	37.22±4.28	39.18±3.75	38.92±3.10	38.54±5.12
PL-2	32.46±5.81	28.74±5.15	29.20±4.87	29.59±2.59	29.14±3.89	29.86±4.32
CL-2	27.88±6.16	25.00±5.30	24.79±4.88	25.98±3.66	25.19±5.11	26.30±4.04
ML-2	43.30±7.29	38.71±6.60	40.05±6.55	40.48±3.49	40.16±5.46	40.99±3.79
DacL-3	36.10±5.28	32.06±5.26	31.33±3.78	32.63±5.32	33.00±3.27	32.19±3.10
PL-3	28.08±4.38	25.28±4.62	25.60±2.51	25.76±4.74	26.32±3.74	25.48±3.65
CL-3	24.50±4.52	22.34±4.36	22.27±2.88	22.66±4.60	23.76±3.94	22.35±3.87
ML-3	32.83±4.74	30.06±4.75	30.08±2.46	28.93±5.86	31.88±3.79	29.98±2.78
DacL-4	16.36±3.32	14.78±2.60	14.61±1.35	14.54±2.06	15.01±2.22	14.68±1.65
PL-4	29.04±4.87	26.06±4.01	26.17±1.59	26.24±3.35	26.64±3.36	25.44±2.09
CL-4	16.38±4.08	19.63±82.13	14.11±1.85	14.60±1.88	14.70±2.83	14.15±2.88
ML-4	25.98±4.65	23.95±11.53	25.30±2.86	23.40±3.02	24.40±1.99	23.56±2.88
			Right cheliped			
DacL-1	32.36±12.14	22.14±4.37	22.22±2.76	22.92±4.43	22.81±2.53	23.71±2.72
PL-1	42.11±6.81	36.69±6.41	38.89±3.83	37.07±5.84	38.88±4.34	35.64±2.85
CL-1	27.40±5.33	24.24±5.35	23.51±4.10	24.44±4.93	24.59±4.20	24.08±3.56
ML-1	40.88±6.41	38.35±20.33	36.60±4.63	37.29±5.52	39.25±4.12	36.38±4.18
DacL-2	41.98±6.77	37.34±5.36	37.20±4.33	38.02±4.30	39.02±4.14	38.38±2.89
PL-2	32.79±5.41	29.77±4.77	30.68±4.74	29.92±3.82	30.22±4.27	30.00±4.26
CL-2	27.31±6.20	25.14±5.13	24.95±5.44	25.19±4.72	26.13±4.03	25.00±3.29
ML-2	44.20±6.79	40.43±6.04	38.56±7.33	40.34±4.68	42.50±3.51	42.12±2.25
DacL-3	35.63±5.12	32.52±4.20	31.97±3.33	32.41±3.56	32.88±3.67	33.02±3.88
PL-3	27.87±4.28	25.78±4.07	24.64±4.48	25.48±3.49	25.79±2.86	24.92±2.74
CL-3	24.77±4.58	22.93±4.34	21.61±4.66	22.90±3.74	24.03±4.20	21.59±2.91
ML-3	33.10±5.27	30.13±4.99	30.30±3.46	30.08±4.16	32.14±4.26	29.39±2.84
DacL-4	16.11±2.91	14.46±2.19	14.78±2.31	14.56±1.64	14.97±2.28	14.72±2.15
PL-4	27.71±5.19	24.23±4.66	24.14±4.80	24.08±5.47	26.54±3.25	24.52±3.01
CL-4	15.06±3.78	12.75±2.78	12.85±3.53	12.47±2.53	14.06±3.31	12.78±1.90
ML-4	24.60±6.70	20.85±4.99	21.44±5.39	20.50±5.80	23.24±3.84	21.55±3.67

DacL-1, DacL -2, DacL -3, DacL 4 is dactilus length foot path 1, 2, 3, 4; PL-1, PL-2, PL-3, PL-4 is propodus length foot path 1, 2, 3, 4; CL-1, CL-2, CL-3, CL-4 is carpus length foot path 1, 2, 3, 4; ML-1, ML -2, ML-3, ML-4 is merus length foot path 1, 2, 3, 4.

Based on the morphometric characters of the left claws measured, PL-1 had an average length greater than that of DacL-1, CL-1 and ML-1; PL-1 values are always greather than of CL-2; and PL-2 value always are smaller than of ML-2.

DacL-3 character was longer than PL-3, CL-3 and ML-3 and on average; PL-4 character was longer than that of DacL-4, CL-4 and ML-4. On the right claw, on average, PL-1 character had a length approaching the length of ML-1 and the values of both were greater than those of DacL-1 and CL-1. The ML-2 character was longer than that of DacL-2, PL-2 and CL-2, and the DacL-3 character was longer than that of ML-3, PL-3 and CL-3, and on average, PL-4 character was greater than that of DacL-4, CL-4 and ML-4. The Mann-Whitney test on the right and left claws of DacL, PL, CL, ML parameters on the first to the fourth walking leg produced the p value of < 0.01, and this shows that all characters were very different in both male and female coconut crabs.

Comparison of all left and right claw parameters measured yielded asymmetric index (AI) values for DacL-1 (-0.094), DacL-2 (-0.005), DacL4 (-0.007) and 0.00 for DacL-3. The characters of PL -1 and PL-4 had respective values of -0.091 and -0.033 while those of PL -2 and PL -3 were 0.00. The characters of CL -1, CL-2 and CL-4 have values -0.059, -0.004 and -0055 respectively while on CL-3 is 0.00. The character of ML-1 and ML-4 had respective values of -0.017 and 0.049, and those of ML -2 and ML-3 were 0.00 respectively. The AI values of the morphometric characters measured are still in their range i.e. between -1 and +1. The comparison of AI shows that the values of the left and right claws compared were between 0 and -1. The AI values of the characters of DacL-1, DacL-2, DacL-4, PL-1, PL-4, CL-1, CL-2, CL-4, ML-1, and ML-4 were < 0. The AI value of < 0 indicates that the left cheliped parameter was greater than right one (heterochely) while the parameters of DacL-3, PL-2, PL-3, CL-3, ML-2 and ML-3 had a value of 0. The AI value of 0 indicates that there is no difference in size between the right and left cheliped parameters (perfect homochely*)*. The Mann-Whitney test result on the AI of the claw parameters shows that the characters PL-4, CL-4 and ML-4 had significantly different AI values at $p < 0.01$.

The diversity coefficient of morphometric characters. Morphometric characters of coconut crabs in the ratio with TL in Daeo Morotai Island, Fitako Doi Island and Laigoma Kayoa Island had varied coefficient values (Table 2). The morphometric character of CL-2/TL of the left claws had the highest diversity coefficient value in males of Daeo population (20.13 mm), Fitako population (22.11 mm), and Laigoma population (21.31 mm). In female coconut crabs, the highest diversity coefficients were found in the morphometric characters of CL-2/TL (19.85 mm) in Daeo population, CL3/TL in Fitako population (21.17 mm) and in Laigoma population (17.29 mm). The morphometric characters of ML-4/TL of the right claw had the highest diversity coefficient in male crabs in Daeo population (22.36 mm) and of CL-4/TL in male crabs in Fitako population (36.07 mm) and in Laigoma (21.75 mm). In female coconut crabs, the highest CL-2/TL character existed in Daeo population (20.24 mm), and ML-4/TL character existed in Fitako population (24.19 mm) and in Laigoma populations (19.89 mm).

The lowest diversity coefficients of the right claws were DacL-3/TL character (9.75 mm) in Daeo population, ML-1/TL (10.42) character in Fitako population and DacL-1/TL character (9.56 mm) in Laigoma population for the male coconut crabs while on female coconut crabs, the lowest diversity coefficients were found in DacL-2/TL character (11.42 mm) in Daeo population, PL-4/TL character (9.06) in Fitako population and DacL-2/TL character (3.68 mm) in population Laigoma. On the left claws, the lowest diversity coefficients were found in DacL-3/TL character (9.65 mm) in Daeo population, ML-4/TL character in Fitako population (8.34 mm) and in Laigoma population (7.39 mm) for the male coconut crabs. In female coconut crabs, the characters of PL-1/TL (7.18 mm) in Daeo population, ML-4/TL (7.46 mm) in Fitako population and DacL-1/TL(5.90 mm) in Laigoma populations were found.

Characters of carapace size with the highest diversity coefficients were HL/TL on male and female coconut crabs in Daeo population (10.34 mm and 10.42 mm respectively) and in Fitako male population (21.55 mm) and TW/TL character on female population in Fitako (9.83 mm) and on male and female crabs in Laigoma populations

(10.70 and 15.09 respectively). The lowest diversity coefficients in Daeo population for the character of CP+r/TL were found on males (6.90 mm) and females (6.15 mm). In Fitako population, the character of Cp-r (9.57) was found in male crabs and Cp+r (4.10 mm) in female ones. In Laigoma population, the character of Cp+r existed in males (4.68 mm) and in females (6.97 mm).

Table 2
The diversity coefficient of the morphometric characters of coconut crabs in Daeo, Fitako and Laigoma

Characters	*Diversity coefficient (%)*					
	Daeo (mm)		*Fitako (mm)*		*Laigoma (mm)*	
	Male	*Female*	*Male*	*Female*	*Male*	*Female*
Left cheliped						
DacL-1/TL	12.12	13.27	11.23	10.28	9.81	5.90
PL-1/TL	10.71	11.23	11.26	9.15	11.05	7.18
CL-1/TL	16.69	17.25	18.28	17.67	12.23	16.46
ML-1/TL	13.20	12.59	21.36	12.58	11.43	9.41
DacL -2/TL	10.95	11.95	15.88	7.93	10.55	9.23
PL-2/TL	14.52	15.70	17.76	11.36	14.89	11.65
CL-2/TL	20.13	19.85	22.11	17.88	21.31	12.51
ML-2/TL	13.83	15.64	21.33	10.69	16.25	10.20
DacL-3/TL	9.65	14.26	16.20	15.55	10.25	10.35
PL-3/TL	12.53	16.30	15.48	18.45	13.36	14.57
CL-3/TL	16.49	17.49	17.02	21.17	15.49	17.29
ML-3/TL	11.07	13.89	13.92	20.64	11.84	11.34
DacL-4/TL	16.50	12.99	17.17	10.89	14.17	9.86
PL-4/TL	12.83	10.90	11.06	8.89	12.37	6.72
CL-4/TL	12.88	19.10	17.42	9.23	17.54	16.27
ML-4/TL	14.19	14.41	8.34	7.46	7.39	8.83
Right cheliped						
DacL-1/TL	12.94	17.11	17.25	16.16	9.56	6.49
PL-1/TL	11.95	14.70	19.55	12.43	10.68	4.07
CL-1/TL	15.57	19.25	16.99	17.93	16.36	10.26
ML-1/TL	12.83	13.33	10.42	13.56	10.66	8.62
DacL-2/TL	10.72	11.42	11.57	10.54	11.76	3.68
PL-2/TL	14.88	14.65	16.47	14.39	14.18	8.23
CL-2/TL	22.19	20.24	20.32	21.99	15.43	10.25
ML-2/TL	13.50	14.45	20.56	14.78	10.51	5.09
DacL-3/TL	9.75	10.60	15.28	10.14	12.01	7.49
PL-3/TL	13.35	14.63	21.08	14.50	11.57	11.50
CL-3/TL	16.96	17.81	23.91	17.12	17.79	12.10
ML-3/TL	13.14	15.13	16.98	13.08	13.45	10.85
DacL-4/TL	14.24	11.89	20.80	10.45	13.32	12.18
PL-4/TL	14.89	14.69	25.99	9.06	11.43	12.60
CL-4/TL	19.97	17.29	36.07	16.76	21.75	13.91
ML-4/TL	22.36	19.81	30.56	24.19	16.97	19.89
TW/TL	7.36	7.73	11.06	9.83	10.70	15.09
Cp+r/TL	6.90	6.15	9.79	4.10	4.68	6.97
Cp-r/TL	8.16	7.50	9.57	5.50	5.43	5.61
HL/TL	10.34	10.42	21.55	9.76	8.63	7.64

DacL: dactilus length, PL: propodus length, CL: carpus length, ML: merus length, TW: thoracic width, TL: thoracic length, Cp+r: Cephalotorax length plus rostrum, Cp-r: Cephalotorax length minus rostrum, HL : head length.

Cluster analysis. Cluster analysis of morphometric character of male and female coconut crabs was constructed based on the distance value of malahonobis. The distance matrix (Table 3) and morphometric character dendogram (Figure 3) of male and female coconut crabs in Daeo Morotai Island show that there was mixing between male and female coconut crabs at the three research stations. The smallest distance is among coconut crab males in station II with coconut crab male station III with a value of 0.5291 while the furthest distance among the female coconut crab in Station I with coconut crab male Station III with a value of 2.1385.

Table 3
Distance matrix based on morphometric character of coconut crabs among stations in Daeo Morotai

Station/Sex	*I - Female*	*I - Male*	*II - Female*	*II - Male*	*III - Female*	*III - Male*
I - Female	0.00000					
I - Male	1.05948	0.00000				
II - Female	0.67837	1.05166	0.00000			
II - Male	1.88365	0.60356	1.34359	0.00000		
III - Female	0.64898	0.98358	0.78565	1.68462	0.00000	
III - Male	2.13852	0.75754	1.51544	0.52910	1.59868	0.00000

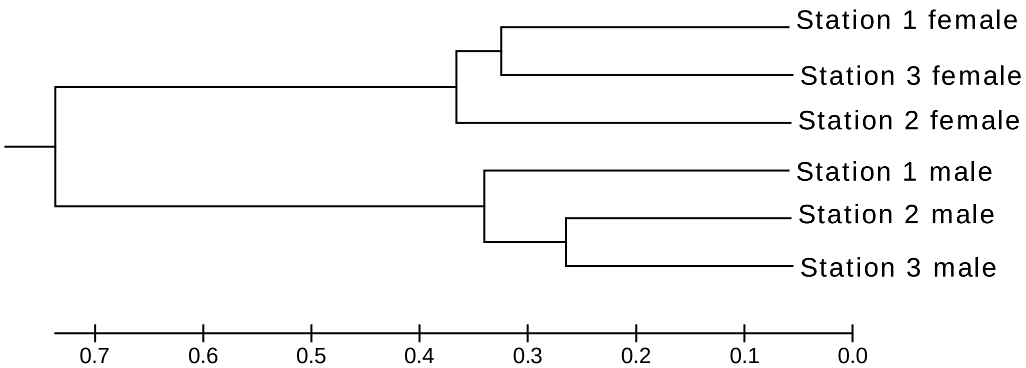

Figure 3. Morphometric character dendogram of coconut crabs based on the stations in Daeo Morotai.

Based on the three sampling sites in North Maluku i.e. Daeo Morotai Island, Laigoma South Halmahera and Fitako North Halmahera Utara, the greatest distance of morphometric character of coconut crabs populations was in Laigoma and Fitako populations (1.8946), and the closest distance was in Daeo and Laigoma populations (0.8851) (Table 4). The dendogram construction (Figure 4) shows that the Daeo and Laigoma populations form one group and separate from the *B. latro* population group from Fitako.

Table 4
The distance matrix of morphometric character of coconut crabs population in Daeo, Laigoma, and Fitako

Location	*Daeo*	*Laigoma*	*Fitako*
Daeo	0		
Laigoma	0.8851	0	
Fitako	1.0157	1.8946	0

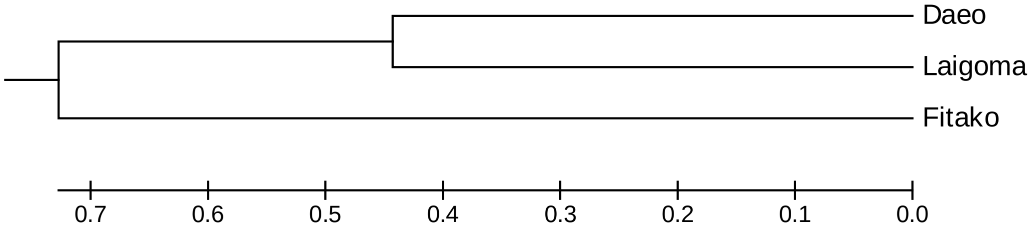

Figure 4. Dendogram of morphometric character of coconut crabs population in Daeo, Laigoma, and Fitako.

Discriminant analysis. Discriminant analysis of male and female coconut crabs was based on the observation stations (Table 5). Discriminant analysis which was performed showing the three stations were not completely separated. Female coconut crabs were precisely classified at 54.7% at station I, 60.6% at station II and 58.7% at station III. Whereas, the male coconut crabs precisely classified at 59.5% at station I, 54.1% at station II and 52.1% at station III respectively.

Table 5

Results of classification of male and female coconut crabs populations in Daeo Morotai Island were based on the discriminant analysis

Location/Sex		*Prediction group (%)*			
		Station I	*Station II*	*Station III*	*Total*
Observation group	Station I - Female	54.7	25.0	20.3	100
	Station II - Female	18.2	60.6	21.2	100
	Station III - Female	21.5	19.8	58.7	100
	Station I - Male	59.5	23.8	16.7	100
	Station II - Male	20.2	54.1	25.7	100
	Station III - Male	21.5	26.4	52.1	100

Based on the location, the discriminant analyses in Daeo, Laigoma and Fitako showed that the morphometric characters of coconut crabs were perfectly classified by 50.0% in Daeo population, by 62.5% in Laigoma population and by 71% in Fitako population (Table 6). The morphometric character of male and female coconut crabs among stations is scattered randomly on the major axis and there is an overlapping of morphometric characters (Figure 5).

Table 6

Results of classification of coconut crabs populations of Daeo, Laigoma and Fitako based on discriminant analysis

Location		*Prediction group (%)*			
		Daeo	*Laigoma*	*Fitako*	*Total*
Observation group	Daeo	50.0	24.7	25.3	100
	Laigoma	12.5	62.5	25.0	100
	Fitako	22.5	6.5	71.0	100

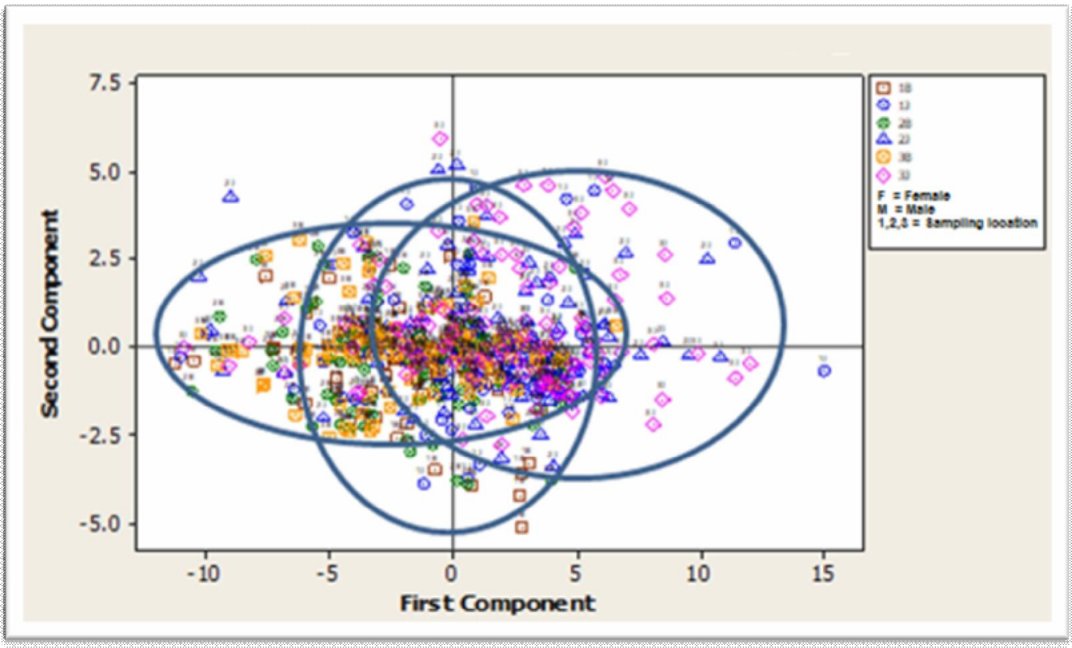

Figure 5. Plot of coconut crabs morphometric distribution on gender in Daeo location (Morotai Island District) was based on the discriminant analysis.

The discriminant analysis shows that the populations of Daeo, Laigoma and Fitako were also not completely separated (Figure 6). Based on the discriminant analysis, it can also be seen that there is a sharing component among the locations caused by the similarity in the morphometric characters. The occurrence of this component sharing shows that all characters measured among the observation stations have similarities.

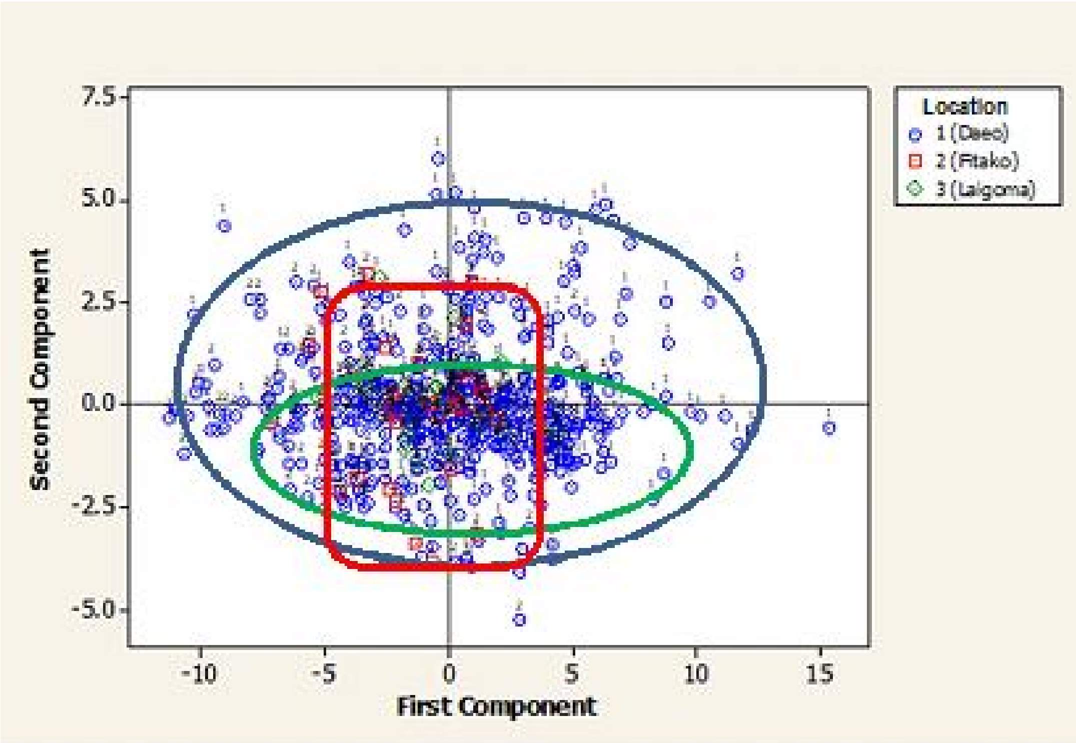

Figure 6. Plot of morphometric distribution of coconut crabs in Daeo, Fitako and Laigoma based on the discriminant analysis.

The relationship of morphometric characters. The morphometric characteristics of the male and female on the left and right sides seen in the correlation were DacL, PL, CL, and ML (Table 7).

Table 7 showed that DacL characters of left cheliped female have a close correlation (52.1%) with negative allometric patterns on male and female. The PL character of right celiped male has a strong correlation of 60.7% and the left was a correlation of 56.7% with negative and isometric allometric patterns on left celiped male. CL characters have a low correlation (< 50%) in both left and right celiped of male and female, whereas the ML character have a strong correlation in right celiped of 60.5% and the left of 63.8% with negative allometric patterns.

Table 7

Correlation of ductyl length (DacL), propodus length (PL), carpus length (CL) and merus length (ML) with thorax length (TL) on right and left sides of male and female

Morphometic character	*Sex*	*Equation*	R^2	*t-hit*	*Equation*	R^2	*t-hit*	*Allometric*	
		Right cheliped			*Left cheliped*			*Right*	*Left*
DacL	Female	Y = 1.961x0.768	0.521	8.048	Y = 1.468x0.864	0.569	2.937	-	-
	Male	Y = 2.480x0.709	0.232	4.131	Y = 1.358x0.895	0.681	3.024	-	-
PL	Female	Y = 2.230x0.748	0.487	5.360	Y = 1.924x0.818	0.567	4.140	-	-
	Male	Y = 2.637x0.716	0.607	8.717	Y = 1.369x0.926	0.301	0.924	-	0
CL	Female	Y = 1.846x0.719	0.338	4.555	Y = 1.510x0.795	0.199	2.096	-	-
	Male	Y = 1.845x0.724	0.405	5.546	Y = 0.046x0.795	0.485	4.426	-	-
ML	Female	Y = 3.097x0.690	0.344	5.282	Y = 2.950x0.707	0.451	6.102	-	-
	Male	Y = 2.688x0.736	0.605	7.848	Y = 2.583x0.753	0.638	7.716	-	-

Description: - = negative allometric; 0 = isometric.

Discussion

Body size based on the morphometric characters. Coconut crabs have different morphometric character size (DacL, PL, CL, ML) in each individual. Character size differences were caused by differences in body size, natural foods availability, disturbance level and environmental conditions suitability. The measured of claws showed a significant difference ($p < 0.05$). Anagnostou & Schubart (2014) measured the length dimensions of carapace length (CL), cephalic shield length (CSL), thoracic length (TL), thoracic width (TW) and found that female crabs were significantly smaller than male crabs, and based on the parameters of cheliped ductilus length (CDL), cheliped propodus width (CPW), cheliped propodus length (CPL), and cheliped merus length (CML), the females are significantly smaller than male coconut crabs. Drew & Hansson (2014) also found clear sexual dimorphism with the male coconut crabs dominating a larger size class than the female coconut crabs. Drew et al (2010) in all studied populations found that male coconut crabs were consistently larger than female coconut crabs.

The claw asymmetry conditions were seen in 10 characters (DacL-1, DacL-2, DacL-4, PL-1, PL-4, ML-1, CL-1, CL-2, CL-4 and ML-4) with AI value < 0 that showed left cheliped larger than right cheliped characters (heterochely). There were six symmetry characters (perfec homochely) i.e DacL-3, PL-2, PL-3, CL-3, ML-2 and ML-3 parameters with AI = 0 values that indicated no difference in size between right and left cheliped. Anagnostou & Schubart (2014) suggest that asymmetry in coconut crabs is commonly observed not only in propodus and dactylus but also in merus. In many species of coconut crabs as well as in many other anumorous and brachiura species, heterochely is more seen in males than females as a result of sexual selection.

The asymmetry conditions in coconut crabs are found in the juvenile phase. In that the phase of coconut crabs and other coenobitidae families using a gastropod shell as a refuge showing ontogenetic carcinization (Tsang et al 2011). Reese (1968) has found that juvenile coconut crabs have the soft pleon similar to other asymmetrical crabs and occupy the shell of the gastropod as a shelter. Concomitant with its growth, the coconut crab left the gastropod shell so that the condition of asymmetry at the beginning of its development weakened and pleonic calcification increased. The asymmetry conditions are influenced by environmental conditions (Harvey 1998).

The weights of Daeo coconut crabs ranged from 50 to 990 grams while the coconut crabs in Fitako and Laigoma weighed less than 300-410 grams and 290-310 grams respectively. Coconut crabs can reach a maximum size of four kilograms (Brown & Fielder 1991; Lavery et al 1995; Hartnoll 1988; Robertson 1991; Stensmyr et al 2005; Anagnostou & Schubart 2014). The weight of Cp+r was between 44.93 and 114.72 grams and that of Cp-r was between 36.72 and 103.40 grams. TL catches ranged from 19.56 to 54.86 mm, TL ranged from 36.67 to 106.98 mm, and HL ranged from 21.54 to 60.73 mm. Whitten et al (1987) stated that the female body size was smaller than the males' size with a maximum thorax length of 55 mm. Drew & Hansson (2014) found some female coconut crabs with a thorax length between 16.9 mm and 51.2 mm max and some male crabs with a thorax length between 19.4 and 76.1 mm. Helagi et al (2015) revealed an average size of 26 mm TL female crabs and 31 mm TL males in Niue, while Pasilio et al (2013) suggested 34.5 mm TL female and 39.0 mm TL male coconut crabs in Tokelau.

Coconut crabs are also found in sizes of 14.3-68.8 mm (males with 16.4-68.8 mm of TL and females with 14.3-47.5 mm of TL) in Okinawa, Japan (Oka et al 2016a). Widiyanti et al (2015) found coconut crabs with a size of 3.00-66.09 mm of TL on Liwo Island, North Maluku. Meanwhile, in Menui, Central Sulawesi, coconut crabs were found with a length of 18-130 mm and weighing of 4-1300 g (Rahman et al 2016) and on Batudaka Island in Central Sulawesi with a size of Cp + r male 4.10-12.40 cm and females 3.92-9.10 cm (Heryanto & Wowor 2017). Gurusu et al (2016) also found coconut crabs in the length of CP + r 18-130 mm and weighed 4 00 1300 g (males) and 48-111 mm and weighed of 300-1110 g (females) in Menui Islands.

***The diversity coefficient of morphometric characters**.* The diversity of morphometric characters was very important in determining the phylogenetic relationship among population and inter-population. The diversity coefficient value represents the morphometric diversity within and among the populations descriptively. The high diversity coefficient within the same populations shows the high diversity of characters; therefore, it is not suitable to serve as the characteristic of the population phenotype. The morphometric character with the lowest diversity coefficient value describes the consistency of its size, so it can be used as the characteristic of the population phenotype. The morphometric characters in left claws of DacL-3 in male crabs and PL-4 in female crabs in Daeo, of PL-4 in male crabs and DacL-2 in female crabs in Fitako and CL-2 in male crabs and DacL-1 in female crabs in Laigoma had low diversity coefficient values. In the right claws, the lowest diversity coefficient was found in DacL-3 character for both male and female crabs in Daeo population. DacL-2 character for male crabs and PL-4 for female crabs were found in Fitako population. Laigoma population had the lowest diversity coefficient on the ML-1 character for male crabs and ML-4 for female crabs. Determination of the characteristics of population phenotype should be tested further to see the significance of these characters in the populations.

The ANOVA test showed that all the characters compared were not significantly different in the population or among the populations because of the p value of > 0.05. Further test showed that the characteristic of PL on the four-walking legs among the populations of Daeo and Fitako were significantly different with the p value of < 0.05. Thus, although it had low diversity coefficients, not all characters can be used as a characteristic of the population phenotype because of the overlapping of the morphometric characters.

***Cluster analysis**.* The similarity of intra-population morphometric characters (between stations in the Daeo population) and inter-population (population of Daeo, Laigoma and Fitako) illustrated that the close similarities of characters were measured by the correlation matrix and dendrogram. Santoso (2002) stated that the similarity analysis was carried out using the hierarchical cluster analysis technique that is by grouping objects based on the similarity of characteristics among the objects. Objects are classified into one or more clusters (groups) so that objects in one cluster will have a resemblance to one another.

The smallest distance in the Daeo population was male between station II and station III with value of 0.5291, while the largest distance was female between station I and station II with value of 1.8837. Dendrogram construction showed that mixing of male and female occurred in all stations in Daeo. The distance of three populations showed that the smallest distance was between Daeo and Laigoma with value of 0.8851, and the largest distance between Laigoma and Fitako with value of 1.8946. The dendrogram construction shows that Daeo and Laigoma populations form one group and are separated from the coconut crab group of Fitako population.

***Discriminant analysis**.* The results of the discriminant function analysis of the morphometric characters measured among the stations at the Daeo site and the third site (Laigoma, Fitako and Daeo) resulted in the grouping based on the percentage of similarity and sharing component values. The smallest of sharing component in Daeo population was male in station III (52.1%) and female between station I and station II. Sharing component among Daeo, Fitako, and Laigoma showed that the smallest value was seen in Daeo population (50.0%) whereas between populations were obtained in Laigoma and Fitako (6.5%).

Discriminant analysis showed that male and female coconut crabs at the three observation stations in Daeo were not perfectly separated from both male and female coconut crabs. Morphometric characters in third station are randomly distributed on the axis X and Y (left and right). Based on the discriminant analysis, it can also be seen that there was a sharing component of each station due to the similarity of morphometric characters among the stations.

The male of coconut crabs have a larger size than female (Amesbury 1980; Drew et al 2010). This study and Anagnostou & Schubart (2014) also found that morphometric character of females carapace and celiped was significantly smaller than males. However, discriminant analysis showed that male and female morphometric (DacL, PL, CL, ML) in in population (between stations in Daeo) and between populations (Daeo, Laigoma, Fitako) occur component sharing. This result made no apparent distinguishing characteristic to characterize the population and between populations in all locations. This research was also supported by coefficient analysis of diversity that the morphometric characters were not significantly different in population nor between populations ($p > 0.05$).

Based on the geography, the distance between the population of Daeo (Regency of Morotai Island) and Laigoma (Regency of South Halmahera) is 260.42 km, the distance between Daeo (Regency of Morotai Island) and Fitako (Regency of North Halmahera) is 76.42 km, the distance between Fitako (North Halmahera Regency) and Laigoma (Halmahera Regency South) is 235.08 km. The population of Daeo is geographically closer to Fitako than to Laigoma. This shows that the geographical distance does not affect the morphometric character formed. This condition is in line with discriminant analysis indicating that the three types of coconut crab populations based on their morphometric characters cannot be separated and classified appropriately, and there is an overlap among the populations. The presence of overlapping distribution shows the similarity of morphometric characters among the populations or locations of the observations. The component-sharing analysis shows that coconut crabs from the Daeo and Fitako populations are classified precisely by 50% and 25.3% respectively. Likewise, Laigoma population and Fitako population are only correctly classified as much as 62.5% and 25% respectively, and Fitako population is correctly classified as much as 71%, and as much as 22.6% is wrongly classified as Daeo population. Estimation in sharing component or index of similarity among populations was conducted using the discriminant analysis result based on the similarity of body size (Suparyanto et al 1999). The value of body size equation gives an explanation of the measured mixing between one population with other populations.

Correlation between morphometric characters. The correlation between claw parameters of DacL, PL, CL and ML with body length indicated that there was a fairly close relationship between right DacL-TL of female (R^2 = 52.11%) and left DacL-TL of male and female (R^2 = 56.94% and R^2 = 68.08%). PL-TL also showed a fairly close relationship of 60.68% in male right claw and female left claw of 56.74%. A close correlation is also found in ML character of left and right sides respectively 60.48% and 63.83%. Based on the correlation values, it showed that the average dactylus, propods and dusk parameters can be used to estimate the carapace length with a correlation value > 50%. Anagnostou & Schubart (2014) on Christmas Island also found a correlation > 50% on cheliped merm parameter length (left CML), right cheliped propodus length (RCPL), right cheliped propodus width (RCPL), right cheliped ductile length (RCDL) and long cheliped right (RCML).

Anagnostou & Schubart (2014) found chelae dimorphism in male and female coconut crabs, while Oka et al (2016b) in Okinawa Japan found no sexual dimorphism in chelae. The strong cap on coconut crabs was used to take food and protect against predatory attacks. Oka et al (2016b) revealed that there was a correlation between body size and ability to tear, the greater the size of the body showed the greater the ability of coconut crabs to rip (pinching force). A strong correlation was also found between the Clawmass index, namely claw length (CL) x claw height (CH) x claw width (CW) with body weight (BW).

Conclusions. The morphometric characters of coconut crabs in Daeo (Island of Morotai), Laigoma (South Halmahera) and Fitako (North Halmahera) are similar; however, the existing population in Daeo (Morotai Island) has a wider distribution of morphometric characters than that in Fitako (North Halmahera) and in Laigoma (South Halmahera). Male coconut crabs generally have a broader distribution of morphometric characters than female ones. The measured morphometric characters cannot be used as phenotypic identifiers although there are parameters that have low diversity coefficients. The ANOVA test result showed that all the characters compared were not significantly different in the population or among populations ($p > 0.05$). Furthermore, the smallest real difference test showed that the characteristic of PP on the four walking legs between the populations of Daeo and Fitako was significantly different with the p value of < 0.05. However, not all characters can be used as phenotypic identifiers because based on the discriminant analysis, component sharing occurred in the compared morphometric character values. The dactylus, propodus and merus parameters can be used to estimate the length of the carapace with a correlation value > 50%.

References

Amesbury S. S., 1980 Biological studies on the coconut crab (*Birgus latro*) in the Mariana Islands. Agriculture Experiment Station, College of Agriculture and Life Sciences, University of Guam, Technical Report No. 17, University of Guam Marine Laboratory Technical Report No. 66, 36 pp.

Anagnostou C., Schubart C. D., 2014 Morphometric characterisation of a population of adult coconut crabs *Birgus latro* (Decapoda: Anomura: Coenobitidae) from Christmas Island in the Indian Ocean. Raffles Bulletin of Zoology 30:136-149.

Baeza J. A., Thiel M., 2007 The mating system of symbiotic crustaceans. A conceptual model based on optimality and ecological constraints. In: Evolutionary ecology of social and sexual systems: crustaceans as model organisms. Duffy J. E., Thiel M. (eds), Oxford University Press, New York, pp. 250-267.

Barnes R. D., 1974 Invertebrate zoology. 3rd edition, W. B. Saunders & Co., Philadelphia, 874 pp.

Brown I. W., Fielder D. R., 1991 Project overview and literature survey. In: The coconut crab: aspects of the biology and ecology of *Birgus latro* in the Republic of Vanuatu. Brown I. W., Fielder D. R. (eds), Australian Centre for International Agricultural Research Monograph, Canberra 8:1-11.

Buden D. W., 2012 Coconut crabs, *Birgus latro* (Anomura: Coenobitidae), of Sorol Atoll, Yap, with remarks on the status of *B. latro* in the Federated States of Micronesia. Pacific Science 66:509-522.

Burggren W. W., McMahon B. R., 1988 Biology of the land crabs. Cambridge University Press, Cambridge, 479 pp.

Drew M. M., Hansson B. S., 2014 The population structure of *Birgus latro* (Crustacea: Decapoda: Anomura: Coenobitidae) on Christmas Island with incidental notes on behaviour. Raffles Bulletin of Zoology 30:150-161.

Drew M. M., Harzsch S., Stensmyr M., Erland S., Hansson B. S., 2010 A review of the biology and ecology of the robber crab, *Birgus latro* (Linnaeus, 1767) (Anomura: Coenobitidae. Zoologischer Anzeiger 249:45-67.

Effendie M. I., 1979 [Method of fisheries biology]. Dewi Sri Foundation Bogor, 112 pp. [in Indonesian].

Eldredge L. G., 1996 *Birgus latro*, 2008 IUCN Red List of Threatened Species, Version 2013.2. Available at: www.iucnredlist.org. Accessed: January, 2013.

Fletcher W. J., Fielder D. R., Brown I. W., 1989 Comparison of freeze- and heat-branding techniques to mark the coconut crab *Birgus latro* (Crustacea, Anomura). Journal of Experimental Marine Biology and Ecology 127:245-251.

Gurusu I., Ramli M., Oetama D., 2016 [The length-weight relationship of coconut crab (*Birgus latro* L.) caught in the Menui Islands]. Jurnal Manajemen Sumber Daya Perairan 2(2):145-152. [in Indonesian]

Hamasaki K., Sugizaki M., Sugimoto A., Murakami Y., Kitada S., 2011 Emigration behaviour during sea-to-land transition of the coconut crab *Birgus latro*: effects of gastropod shells, substrata, shelters and humidity. Journal of Experimental Marine Biology and Ecology 403:81-89.

Hartnoll R. G., 1988 Evolution, systematics and geographical distribution. In: Biology of the land crabs. Burggren W. W., McMahon B. R. (eds), Cambridge University Press, Cambridge, pp. 6-54.

Hartnoll R. G., 2001 Growth in Crustacea - twenty years on. Hydrobiologia 449:111-122.

Harvey A. W., 1998 Genes for asymmetry easily overruled. Nature 392:345-346.

Helagi N., Tafatu J., Bertram I., Moore B., Linawak M., Pakoa K., 2015 Status of the coconut crab *Birgus latro* in Niue. Pacific Community, Noumea, New Caledonia, 32 pp.

Helfman G. S., 1977 Agonistic behaviour of the coconut crab, *Birgus latro* (L.). Ethology 43(4):425-438.

Heryanto., Wowor D., 2017 [Population studies on robber crab in Batudaka Island of Togean Islands, Central Sulawesi and recomendation on population management]. Jurnal Biologi Indonesia 13(1):149-156. [in Indonesian]

Kessler C. C., 2006 Management implications of a coconut crab (*Birgus latro*) removal study in Saipan, Commonwealth of the Northern Mariana Islands. Micronesica 39(1):31-39.

Kumar S. K., Tamura, Nei M., 1993 MEGA. Molecular Evolutionary Genetics Analysis. Version 3.0. Pennsylvania (US). Avalaible at: http://www.megasoftware.net/MEGA-v1.01.pdf. Accessed: September, 2016.

Lavery S., Moritz C., Fielder D. R., 1995 Changing patterns of population structure and gene flow at different spatial scales in *Birgus latro* (the coconut crab). Heredity 74: 531-541.

Lee S. Y., 1995 Cheliped size and structure: the evolution of a multifunctional decapod organ. Journal of Experimental Marine Biology and Ecology 193:161-176.

Motoh H., Kuronuma K., 1980 Field guide for the edible crustacean of the Philippines. Southeast Asian Fisheries Development Center (SEAFDEC) Aquaculture Department Publication, Iloilo Philippines, 69 pp.

Oka S., Miyamoto K., Matsuzaki S., 2016a Long-term sedentary behavior of coconut crabs in their northernmost range. International Journal of Pure and Applied Zoology 4(2):174-178.

Oka S. I., Tomita T., Miyamoto K., 2016b A mighty claw: pinching force of the coconut crab, the largest terrestrial crustacean. PLoS ONE 11(11):e0166108.

Pasilio T., Pereira F., Rikim K., Pakoa K., Bertram I., 2013 The status of reef invertebrate resources and recommendations for management at Tokelau. Noumea, New Caledonia: Secretariat of the Pacific Community, 32 pp.

Permenhut, 2008 [Forestry minister's regulation Number: P.57/Menhut-II/2008 concerning the strategic direction of national species conservation 2008-2018]. [in Indonesian]

Rahman A., Ramli M., Kamri S., 2016 [Study of coconut crab density in different habitats at Menui Islands, Morowali District]. Jurnal Manajemen Sumber Daya Perairan 2(2):153-159. [in Indonesian]

Reese E. S., 1968 Shell use: an adaptation for emigration from the sea by the coconut crab. Science 161:385-386.

Reese E. S., Kinzie R. A., 1968 The larval development of the coconut or robber crab *Birgus latro* (L.) in the laboratory (Anomura, Paguridae). Crustaceana Supplement 2:117-144.

Ricker W. E., 1975 Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada No. 191, 382 pp.

Robertson M., 1991 Husbandry and moulting behaviour of the robber or coconut crab *Birgus latro*: at London Zoo. International Zoo Yearbook 30:60-67.

Sato T., Yoseda K., Okuzawa K., Suzuki N., 2010 Sperm limitation: possible impacts of large male-selective harvesting on reproduction of the coconut crab *Birgus latro*. Aquatic Biology 10:23-32.

Schiller C., Fielder D. R., Brown I. W., Obed A., 1991 Reproduction, early life-history and recruitment. In: The coconut crab: aspects of the biology and ecology of *Birgus latro* in the Republic of Vanuatu. Brown I. W., Fielder D. R. (eds), Australian Centre for International Agricultural Research Monograph, Canberra 8:13-34.

Santoso S., 2002 [Multivariate statistics SPSS exercise book]. PT Elex Media Komputindo, Jakarta, 343 pp. [in Indonesian]

Stensmyr M. C., Erland S., Hallberg E., Wallen R., Greenaway P., Hansson B. S., 2005 Insect-like olfactory adaptations in the terrestrial giant robber crab. Current Biology 15:116-121.

Suparyanto A., Purwadaria T., Subandriyo, 1999 [Estimation of genetic distances and factors that differentiate sheep and sheep groups in Indonesia through morphological analysis approaches]. Jurnal Ilmu Ternak dan Veteriner 4:80-87. [in Indonesian]

Tamura K., Peterson D., Peterson N., Stecher G., Nei M., Kumar S., 2011 Mega 5: molecular evolutionary genetics analysis using maximum likelihood, evolutionary distance, and maximum parsimony methods. Molecular Biology and Evolution 28(10):2731-2739.

Tsang L. M., Chan T. Y., Ahyong S. T., Chu K. H., 2011 Hermit to king, or hermit to all: multiple transitions to crab-like forms from hermit crab ancestors. Systematic Biology 60:616-629.

Walpole R. E., 1992 [Introduction to statistics]. 3rd edition, Gramedia Main Library, Jakarta, 515 pp. [in Indonesian]

Wang F. L., Hsieh H. L., Chen C. P., 2007 Larval growth of the coconut crab *Birgus latro* with a discussion on the development mode of terresterial hermit crabs. Journal of Crustacean Biology 27(4):616-625.

Whitten A. J., Mustafa M., Henderson G. S., 1987 [Celebes ecology]. Gadjah Mada University Press, Indonesia, 844 pp. [in Indonesian]

Whitten T., Henderson G. S., Mustafa M., 2002 The ecology of Indonesia Series. Vol. 4. The ecology of Sulawesi. Periplus Editions, Hong Kong, 774 pp.

Widiyanti S. E., Marsoedi, Sukoso, Setyohadi D., 2015 Resource management of coconut crab (*Birgus latro*) in Liwo Island, North Maluku of Indonesia. Journal of Biodiversity and Environmental Sciences 6(5): 343-351.

Received: 11 May 2018. Accepted: 25 August 2018. Published online: 26 October 2018.

Authors:
Rugaya Serosero, Program Study of Aquatic Resources Management, Faculty of Fisheries and Marine Science, Khairun University, Street of Gambesi Campus, 97719, North Moluccas, Indonesia; Post Graduate Student of Program Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Street of Agatis Darmaga Campus, 16680, West Java, Indonesia, e-mail: rugayaserosero@yahoo.co.id
Sulistiono, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Street of Agatis Darmaga Campus, 16680, West Java, Indonesia, e-mail: onosulistiono@gmail.com
Nurlisa Alias Butet, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Street of Agatis Darmaga Campus, 16680, West Java, Indonesia, e-mail: n.butet@gmail.com
Etty Riani, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Street of Agatis Darmaga Campus, 16680, West Java, Indonesia, e-mail: etty_riani_harsono@yahoo.com

How to cite this article:
Serosero R., Sulistiono, Butet N. A., Riani E., 2018 Morphometric characteristics of coconut crabs (*Birgus latro* Linnaeus, 1767) in North Moluccas Province, Indonesia. AACL Bioflux 11(5):1616-1632.