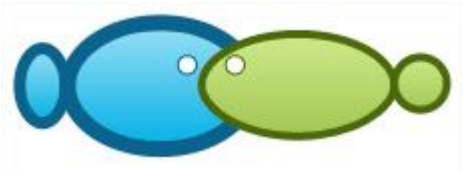

The morphological characteristics of South Sulawesi's giant freshwater prawn *Macrobrachium rosenbergii*

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Abstract. This research aimed to find out the morphological characteristics of six wild populations of giant freshwater prawn *Macrobrachium rosenbergii* in South Sulawesi. Evaluation of 31 morphometric characters were conducted on 145 samples of giant freshwater prawns originating from three locations, namely Waelawi River in North Luwu, Kariango river in Pinrang and Kalibone River in Pangkep. The prawn samples were discriminated between male and female prawns hence six prawn populations were formed. Results of research showed that coefficient of variation (CV) tended to be high (2.72-32.50%), and the morphometric characteristics of six populations were significantly different ($p < 0.001$). Population of male giant freshwater prawns was more dispersed than population of female giant freshwater prawns. The farthest kinship distance (based on sex difference) was obtained between male and female giant freshwater prawns from Kariango population. The prawn from Kariango population could be used in breeding program activities.

Key Words: *Macrobrachium rosenbergii*, morphology, wild, South Sulawesi.

Introduction. Freshwater prawn of genus *Macrobrachium* Bate, 1868 (Crustacea: Palaemonidae) is the decapoda-crustacea group that is quite large in number of species (Jalihal et al 1993; Liu et al 2007). There are approximately two hundred ten species of the prawn (Short 2004), and Indonesia is indicated to still have wild species of giant freshwater prawns spread from Aceh to Papua.

Wild species' adaptation toward different environments can become a discriminator of species between different populations. Discrimination in wild prawn species in Sulawesi includes the ability of immune response (Amrullah et al 2014) and genetic variation (Wahidah et al 2009) between populations. Information of genetic variation can be obtained through the evaluation of the genotypic and phenotypic characteristics. The characteristic value is obtained by measuring phenotypic morphology of individuals in a population by morphometric (such as Truss morphometric) and meristic analyses. Several studies have evaluated the phenotypic characters for few species as: *Macrobrachium vollenhovenii* Herklots, 1851 in Côte d'Ivoire river (Konan et al 2010), *Macrobrachium australe* in Reunion Island (Zimmermann et al 2012) and *Macrobrachium grandimanus* in Hawai (Sethi et al 2013).

Morphometrics is an empirical function of geometry and biology (Bookstein 1997). Morphometric measurement has a specific function to describe a shape, and is a type of measurement most frequently used to describe populations as expressed (Murta 2000; Silva 2003; Turan 2004). Morphometric characteristics of a population is the result of interaction between the genotype and the environment. The phenotype of a population can be identified through morphometric characteristics. Morphometric characteristics of a population is required to determine the value of the proportion of body parts that can be consumed larger so that it can be used as a baseline in designing breeding programs.

This research aimed to find out the morphological characteristics of six wild populations of giant freshwater prawn, *Macrobrachium rosenbergii* in South Sulawesi using morphometric methods.

Material and Method. This research was conducted from August 2013 to July 2014. The sampling locations were Waelawi River 120^{o}19'59.961'' E and 2^{o}52'39.7'' S (Balease Watershed, North Luwu), Kariango River 119^{o}37'21.061'' E and 3^{o}52'57.268'' S (Sawitto-Kariango-Rappang Watershed, Pinrang) and Kalibone River 119 ^{o}35'7.014'' E and 4^{o}54'9.03'' S (Sangkara Watershed, Pangkep).

Sample collection. Sample collection was conducted three times at each location (river). Total of samples from Waelawi River and Kalibone River were 50 prawns (25 males and 25 females) for each location and sample from Kariango River were 45 prawns (20 males and 25 females).

Morphological measurement. Morphological measurement was based on Dall (1957) and Lester (1983) that were modified. The morphological measurement used digital caliper (accuracy 0.01 mm). Symbol and definition of morphological characteristics measured were presented in Table 1.

Statistical analysis. Morphological data were analyzed using Excel 2007 program, Xlstat 2014 and SPSS 16 programs. Mean, standard deviation, coefficient of variation were analyzed descriptively, disperse of population was analyzed based on Principal Component Analysis *(*PCA), discriminating characteristic evaluation was based on Discriminant Analysis (DA) and kinship evaluation was based on Agglomerative Hierarchical Clustering (AHC).

Avoiding the effects of different size and ages differences, characteristic values were standardized based on equation $M_s = M_o(L_s/Lo)^b$ as formulated by Konan et al (2010). M_s was standardized individual characteristics, L_s = standard average length, L_o = standard length of individual, b = slope of regression of $\log_{10}M_o$ on $\text{Log}_{10}L_o$ as formulated by Konan et al (2010), Lleonart et al (2000) and Ferrito et al (2007).

Table 1

Symbol, characteristics and definition characteristic morphology giant freshwater prawn

Symbol	*Characteristics*	*Definition of characteristic*
TBL	Total body length	The distance between the tip of the rostrum and the tip of the telson, body straightened
SL	Standard length	The distance between the base of eye and the base of the uropode
HL	Head length	The distance between the tip of the rostrum and the base of the carapace
RL	Rostrum length	The distance between the tip of the rostrum and the posterior border (the eye)
CL	Carapace length	The distance between the eye and the base of the carapace
CW	Carapace width	The widest part of the last rostral spine
CH	Carapace height	The highest point between the top and the bottom of the carapace
TAL	Total abdominal length	The distance between the first segment and the tip of the telson
SAL	Standard abdominal length	The distance between the first segment and the tip of the sixth segment
CF_1	Circumference of the first segment	The circumference of the first segment
CF_2	Circumference of the second segment	The circumference of the second segment
CF_3	Circumference of the third segment	The circumference of the third segment
CF_4	Circumference of the fourth segment	The circumference of the fourth segment
CF_5	Circumference of the fifth segment	The circumference of the fifth segment
CF_6	Circumference of the sixth segment	The circumference of the sixth segment
WS_1	Width of the first segment	The widest point of the first segment
WS_2	Width of the second segment	The widest point of the second segment
WS_3	Width of the third segment	The widest point of the third segment
WS_4	Width of the fourth segment	The widest point of the fourth segment
WS_5	Width of the fifth segment	The widest point of the fifth segment
WS_6	Width of the sixth segment	The widest point of the sixth segment
LS_1	Length of the first segment	The distance between the carapace and the boundary between the first and second segments
LS_2	Length of the second segment	The distance between the boundary of the first and second segment and the boundary of the second and third segments
LS_3	Length of the third segment	The distance between the boundary of the second and third segment and the boundary of the third and fourth segments
LS_4	Length of the fourth segment	The distance between the boundary of the third and fourth segment and the boundary of the fourth and fifth segments
LS_5	Length of the fifth segment	The distance between the boundary of the fourth and fifth segment and the boundary of the fifth and sixth segments
LS_6	Length of the sixth segment	The distance between the boundary of the fifth and sixth segment and the telson
CAA	Circumference of the anterior abdomen	The distance (circumference of the boundary of the fifth and sixth segments)
CPA	Circumference of the posterior abdomen	The distance (circumference of the boundary of the second and third segments)
TL	Telson length	The distance between the base and the tip of the telson
TW	Telson width	The widest point of the telson

Results

Coefficient of variation. The results demonstrated that the range of the coefficient of variation of males (4.68-32.50%), was higher than females (2.72-28.55%) (Table 2). The highest range of the coefficient of variation of males was observed in Kariango population, while the highest range for females was observed in Waelawi population

Table 2

The Coefficient of Variation (CV) of the male and female giant freshwater prawn population morphological characteristics of Waelawi River, Kariango River and Kalibone River

Characteristics	*CV (%) of Waelawi*		*CV (%) of Kariango*		*CV (%) of Kalibone*	
	Male	*Female*	*Male*	*Female*	*Male*	*Female*
TBL	9.08	2.72	4.68	9.23	13.51	27.69
SL	32.19	5.69	23.94	20.43	20.40	21.89
HL	7.69	3.65	8.45	13.09	12.44	23.77
RL	20.38	19.56	8.09	20.12	13.38	23.72
CL	15.53	8.77	10.93	18.81	10.37	19.34
CW	17.30	16.71	13.09	17.05	10.61	17.51
CH	18.97	9.45	12.73	9.70	12.96	16.31
TAL	8.53	4.63	6.26	6.93	14.95	27.62
SAL	9.08	5.84	15.95	7.66	15.50	27.83
CF_1	9.65	7.15	12.40	13.21	13.55	20.48
CF_2	10.46	4.58	12.75	10.54	13.39	19.19
CF_3	11.47	5.17	7.78	14.12	13.58	18.34
CF_4	12.33	5.31	14.43	14.40	14.51	12.62
CF_5	14.30	8.75	16.95	15.34	13.52	15.25
CF_6	15.90	7.67	15.18	18.33	13.87	10.38
WS_1	7.29	10.93	12.03	10.13	10.00	19.10
WS_2	8.15	12.04	24.04	10.47	11.00	15.49
WS_3	7.84	13.65	12.94	8.45	10.65	23.45
WS_4	16.61	12.82	14.80	18.84	11.70	24.21
WS_5	12.14	12.34	14.65	10.84	11.24	21.11
WS_6	18.36	13.81	16.99	12.79	10.40	20.81
LS_1	22.18	23.34	21.16	22.64	10.01	22.90
LS_2	7.05	11.34	16.41	9.38	13.77	16.42
LS_3	6.65	10.81	15.80	10.39	13.30	17.10
LS_4	16.83	13.93	32.50	11.53	14.60	14.75
LS_5	13.66	12.71	13.37	10.15	15.17	18.57
LS_6	7.76	9.29	16.83	10.52	13.46	18.93
CAA	11.29	20.44	8.68	13.83	17.01	20.06
CPA	15.64	11.84	14.47	14.02	14.97	15.27
TL	9.70	4.98	7.07	7.63	14.98	23.56
TW	26.70	28.55	15.31	23.13	12.20	15.35

Principal component analysis. PCA shown in Figure 1 indicate that in general the morphology of female giant freshwater prawns in the three populations were separate (lying in different quadrants), while male prawns tended to be close (centroid) closer.

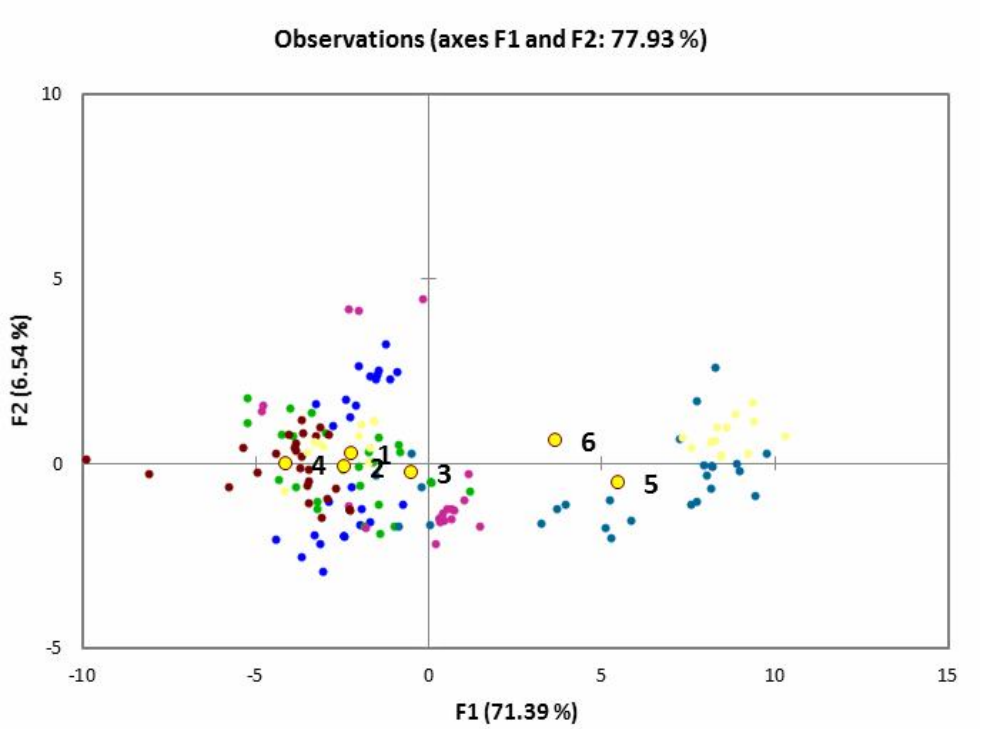

Figure 1. The distribution of the morphological characteristics of the giant freshwater prawn populations of Waelawi River, Kariango River and Kalibone River (1 = the male population of Waelawi River; 2 = the male population of Kariango River; 3 = the male population of Kalibone River; 4 = the female population of Waelawi River; 5 = the female population of Kariango River; 6 = the female population of Kalibone River).

Difference between population. Analysis of pairwise group comparison (Table 3) steps 1–23 indicated a very real difference ($p < 0.001$), at the last step (step 23) female population in Waelawi and that in Kariango had the biggest difference (21.815), while the smallest difference value was found between male population in Waelawi and that in Kalibone (3.908).

Table 3

Pairwise group comparison of the male and female giant freshwater prawn populations of Waelawi River, Kariango River and Kalibone River

Populations		*Populations*					
		Waelawi Male	*Kariango Male*	*Kalibone Male*	*Waelawi Female*	*Kariango Female*	*Kalibone Female*
Waelawi Male	F						
	Sig.						
Kariango Male	F	4.726					
	Sig.	0.000					
Kalibone Male	F	3.908	4.114				
	Sig.	0.000	0.000				
Waelawi Female	F	6.215	4.425	5.126			
	Sig.	0.000	0.000	0.000			
Kariango Female	F	16.438	15.509	9.095	21.815		
	Sig.	0.000	0.000	0.000	0.000		
Kalibone Female	F	19.480	16.119	13.809	14.682	11.863	
	Sig.	0.000	0.000	0.000	0.000	0.000	

Cross validation. Cross validation (Table 4) indicated that proportion of female population classification was higher, that are 92%, 80% and 76% prawns populations from Kalibone, Kariango and Waelawi respectively, compared to the male population that the values were 65%, 64% and 60% of the prawn populations from Kalibone, Waelawi and Kariango, respectively. Discriminating function that discriminated the six populations of giant freshwater prawns was considered to be proper to classify the membership of each population that was evaluated, where 83.4% individuals of giant freshwater prawns had been grouped according to their origins, and 73.1% of individuals were grouped based on cross validation between populations.

Table 4

Cross-validation of individual classification of the giant freshwater prawn populations of Waelawi River, Kariango River and Kalibone River (a - 83.4% of original grouped cases correctly classified; b - 73.1% of cross-validated grouped cases correctly classified)

	Populations	*Predicted group membership*						*Total*
		Waelawi Male	*Kariango Male*	*Kalibone Male*	*Waelawi Female*	*Kariango Female*	*Kalibone Female*	
Original (%)[a]	Waelawi Male	76.0	12.0	12.0	0.0	0.0	0.0	100.0
	Kariango Male	0.0	76.0	16.0	8.0	0.0	0.0	100.0
	Kalibone Male	10.0	10.0	80.0	0.0	0.0	0.0	100.0
	Waelawi Female	4.0	8.0	12.0	76.0	0.0	0.0	100.0
	Kariango Female	0.0	4.0	0.0	0.0	96.0	0.0	100.0
	Kalibone Female	0.0	0.0	4.0	0.0	0.0	96.0	100.0
Cross-validated (%)[b]	Waelawi Male	64.0	16.0	12.0	8.0	0.0	0.0	100.0
	Kariango Male	4.0	60.0	20.0	16.0	0.0	0.0	100.0
	Kalibone Male	10.0	20.0	65.0	0.0	5.0	0.0	100.0
	Waelawi Female	4.0	8.0	12.0	76.0	0.0	0.0	100.0
	Kariango Female	0.0	4.0	16.0	0.0	80.0	0.0	100.0
	Kalibone Female	0.0	0.0	4.0	0.0	4.0	92.0	100.0

Kinship relationship. Results of kinship relationship analysis based on phenotypic (morphology) (Table 5) indicated that female population in Waelawi had the farthest kinship with female population in Kariango, followed successively by female population in Waelawi with female population in Kalibone and male population in Kariango and female population in Kariango. When the data were mapped in a dendrogram the Figure 2 was obtained.

Table 5

Matrix of kinship relationship based on fenotype (morphology) of giant freshwater prawn *Macrobrachium rosenbergii* populations in Waelawi River, Kariango River and Kalibone River

Populations	*Kinship distance*					
	Waelawi Male	*Kariango Male*	*Kalibone Male*	*Waelawi Female*	*Kariango Female*	*Kalibone Female*
Waelawi Male	-					
Kariango Male	19.042	-				
Kalibone Male	17.030	27.185	-			
Waelawi Female	34.412	25.344	44.224	-		
Kariango Female	95.693	107.310	84.085	127.425	-	
Kalibone Female	79.106	90.436	67.510	109.151	26.673	-

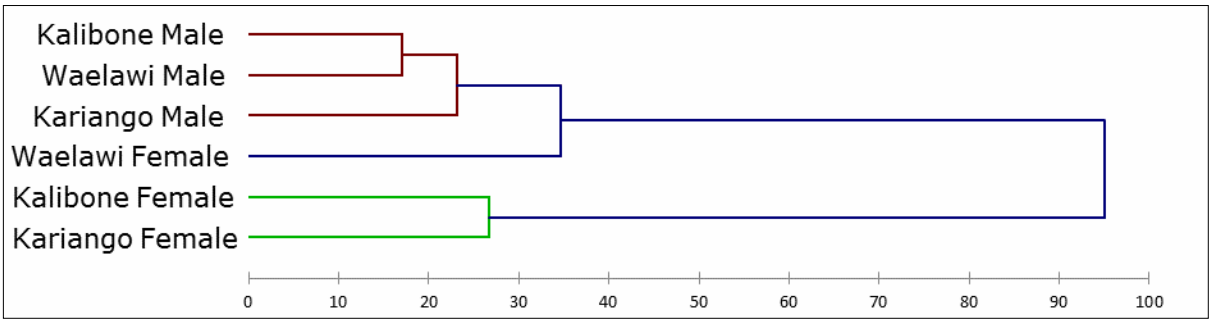

Figure 2. Dendrogram of kinship relationship based on fenotype (morphology) of giantfreshwater prawn Macrobrachium rosenbergii populations in Waelawi River, Kariango River and Kalibone River

Discussion. Statistical analysis was obtained from the three sampling sites, in which each site was grouped into two populations based on gender differences of the tested prawns. Grouping the tested prawns into gender was due to the difference in growth, which is closely related to the morphology. Male prawns tend to have larger dimensions than the female prawns. A similar result was observed in *Macrobrachium iheringi* (Fransozo et al 2004) and *Macrobrachium brasiliensis* (Mantelatto & Barbosa 2005).

Our data showed that the value of CV of the male population was higher than the female population. A similar result was obtained in *M. vollenhovenii* Herklots (1.93%-19.83%) (Konan et al 2010) and *Macrobrachium lar* (Fabricius, 1798) (9.46%-20.48%) (Sethi et al 2013). The higher range of CV indicates more heterogeneous morphological characters as reported by Ferrito et al (2007). In the male population, morphological characters that have higher CV than 25% are the standard length (SL), length of the fourth segment (LS_4) and telson length (TL); while in females are total body length (TBL), total abdominal length (TAL), standard abdominal length (SAL) and telson length (TL). All of these morphological characters are associated with the size of body parts that can be consumed by humans. Hence, the selection can be performed on these characters. A population that has high diversity (variation) is classified as a wide-spread genetic variability, from which the selection can be performed due to more heterogeneous characters.

Results of pairwise group comparison gave information that the six populations were significantly different ($p < 0.001$) with the biggest difference value found in female population. This indicated that the six populations had different morphological characteristics. The difference of morphological characteristics in female population could be affected by environmental factors such as geographical location (Vergamini et al 2011; Pantaleão et al 2014; Chen et al 2015), where population of Waelawi was in Watershed Balease with its estuary to Bone Bay, population of Kalibone in Watershed Sangkara with its estuary to Flores Sea and Makassar Strait, and population of Kariango in Watershed Sawitto-Kariango-Rappang with their estuary to Makassar Strait. Based on

the geographical locations of the three rivers it could be stated that probably there was no mixture of populations because there was a geographical barrier.

Based on PCA analysis, population of male giant freshwater prawns was closer and could form a group, compared to that of female prawns which tended to be more concentrated in a certain quadrant based on population. The same condition was observed in kinship dendrogram of giant freshwater prawns (Figure 2), where male populations were in the same cluster, while female populations were in a different cluster with a farther kinship. This condition explained that several individuals in male population tended to have the same morphological characteristics as the male individuals in other male populations. The phenomenon could be explained in that even though male population was geographically isolated, several characteristics were still maintained during the occurrence of gene flow, so some male individuals still had similarities to other male individuals in different populations.

Placement of individuals based on their populations in the results of cross validation analysis (Table 4) indicated that female populations had a high morphological similarity in their own population compared to other populations, while male population individuals had a morphological similarity to individuals in other populations. Morphological similarity indicates an intersection between populations, observed with the presence of a population characteristic that is also characterized by another population. Morphological similarity in the form of similar body size in some characteristic can be caused by a genetic factor. Such a genetic factor can be caused by gene flow as explained by Parenrengi et al (2007) and Kusmini et al (2010), specifying that value of body size similarity describes the presence of measured mixture caused by the presence of a trait that is maintained when gene flow occurs.

Information regarding high CV value, significant morphological differences between populations, cross-validation, and the kinship distance between wild populations of giant prawns can be used to design a breeding program. The results show that the farthest kinship distances are females Waelawi - females Kariango couples, females Waelawi - females Kalibone couples, and males Kariango - females Kariango couples, respectively. However, only the population of males - females Kariango couples can be used for the breeding. The couples with the kinship distances were farther than the males - females Kariango couples cannot be bred because the breeding pair was female. Therefore, the male-female population Kariango is recommended for selective breeding programs in natural populations of the Sulawesi freshwater prawns to obtain an increase in the performance of morphology.

Conclusions. The differences in morphological characters found in female populations may be influenced by environmental factors such as geography. The Waelawi population resides in the Watershed Balease, which flows into the Bone Bay. The population of Kalibone is located in the Watershed Sangkara, which flows into the Flores Sea and Makassar Strait, while the Kariango population is in the Watershed Sawitto-Kariango-Rappang, which flows into Makassar Strait. There were differences of morphological characteristics between male and female giant freshwater prawns in six populations originating from three rivers in South Sulawesi. Differences in morphological characteristics and kinship distance between male and female populations in Kariango could be used in breeding program activities.

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