PATTERNS OF MORPHOMETRIC VARIABILITY IN THREE STOCKS OF FARMED TIGER SHRIMP, *Penaeus monodon*, IN INDONESIA AND ITS APPLICATION FOR SELECTIVE BREEDING[1]

(Pola Keragaman Morfometrik pada Tiga Populasi Udang Windu (*Penaeus monodon*) di Indonesia dan Aplikasinya untuk Perbaikan Genetik)

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ABSTRACT

Conventional genetic improvement programs still rely on and exploit the patterns and amount of variation in the phenotype of interest that understanding both aspects is of great importance. This study was aimed to explore those important aspects and relate them with the context of breeding program. Three stocks of farmed tiger shrimp derived from brood stock originated from Aceh, Cilacap and Sumbawa, respectively, were sampled and measured for variability in 22 morphometric traits. The patterns of variability among traits were analyzed descriptively while those between stocks were analyzed using F tests. Exploration to find the best estimators for tail weight was conducted using correlation coefficient and multiple stepwise regressions. Among-traits variation was strongly characterized by the type of data in that weight measured traits were twice higher in their variation relative to those length measured traits. With several exceptions, levels of variation among stocks, in descending order, were Aceh, Cilacap, and Sumbawa. In pairwise comparisons, contrasts between the Aceh and the Cilacap and between the Aceh and the Sumbawa yielded most number of traits which were statistically significant, while that between Cilacap and the Sumbawa yielded the least.. Morphometric traits which best explained variation in the tail weight were combination of partial length, anterior and posterior abdominal circumferences and the endopod. Potential and conditional implications of these results in the context of selective breeding are discussed.

Keywords: morphometric traits, breeding program, tiger shrimps, *Penaeus monodon*.

ABSTRAK

Program perbaikan genetik secara konvensional mengandalkan dan mengeksploitasi pola-pola dan besarnya keragaman genetik pada karakter fenotipik sehingga pemahaman tentang kedua aspek tersebut sangat penting. Penelitian ini ditujukan untuk mengeksplorasi pola dan besarnya keragaman pada beberapa karakter fenotipik udang windu dan mengetahui karakter fenotipik terbaik untuk seleksi peningkatan bobot tanpa kepala. Tiga stok udang windu hasil budidaya di tambak yang masing-masig merupakan keturunan induk udang windu dari perairan Aceh, Cilacap dan Sumbawa dikoleksi dan diukur keragaman pada 22 karakter morfometriknya. Pola-pola keragaman antar karakter fenotipik dianalisis secara deskriptif sedangkan pola keragaman antar stok dianalisis menggunakan uji F. Eksplorasi untuk mendapatkan karakter fenotipik terbaik penduga bobot dilakukan dengan uji koefisien korelasi dan regresi berganda. Keragaman antar karakter fenotipik sangat ditentukan jenis karakter fenotipik yang diukur. Keragaman pada karakter yang diukur dengan satuan berat dua kali lebih besar dari pada keragaman karakter yang diukur dengan satuan panjang. Dengan beberapa perkecualian, urutan tingkat keragaman karakter fenotipik antar stok dari rendah ke tinggi adalah Aceh, Cilacap dan Sumbawa. Pada pembandingan berpasangan, banyaknya karakter fenotipik yang berbeda nyata terbanyak pada pembandingan antara Aceh dengan Cilacap dan Aceh dengan Sumbawa sedangkan yang paling sedikit terdapat pada pembandingan antara Cilacap dengan Sumbawa. Karakter morfometrik yang paling baik dalam menjelaskan keragaman bobot tanpa kepala adalah panjang parsial, lingkar abdomen anterior, lingkar abdomen posterior, dan endopod. Implikasi dari hasil-hasil penelitian ini dalam kaitan dengan program perbaikan genetik didiskusikan.

Kata kunci: karakter morfometrik, program perbaikan genetik, udang windu, *Penaeus monodon*.

INTRODUCTION

Breeding program as a way to improve performance of economically important traits has been widely applied with aquaculture species. Despite progress achieved by the fields of

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molecular genetics, the breeding programs, to a very high extent, still rely on and exploit the information of variation in the phenotypic traits of interest. Hence the understanding of profile, amount and genetic nature of the traits is of great importance. Patterns of morphometric variation among traits for instance, may provide rough insight on the possibility of performing genetic improvement on the trait of interest. Specifically, genetic improvement would be more likely for traits with high variation relative to those with low level of variation. Likewise, different levels of morphometric variation among different stocks, particularly in cases where variation due to environmental effects can be minimized, may indicate that variation in morphometric trait has genetic bases and hence is possible to be genetically improved (Chow and Sandifer, 1991).

In Indonesia, several locations such as Aceh, Cilacap, and Sumbawa, have been widely known as producers of wild-caught brood stocks (Imron *et al*., 1999; Sugama *et al*., 1998). Enzyme-electrophoretic survey of these stocks found genetic variation within the Sumbawa stock was the lowest while that within the other two were comparable. (Imron *et al*., 1999) Whether these attributes will also be reflected in morphometric traits has not been assessed yet.

Among variety of traits, growth as often measured in body weight, either as total or as particular parts of the body, due to economic importance, is of particular interest for most breeding programs. In crustaceans, the edible portion of the animal lies in the abdominal portion, i.e. part of the body seized at the intersection between the body and the carapace, is of commercially important trait that individuals with higher proportion of tail weight are preferable. Lester (1983) called this part of the body as "tail weight". Due to nature of the trait, genetic approach to improve tail weight must be conducted by sacrificing the animals and calculating breeding value of the relatives. Alternatively, it can also be approached by looking at the external morphological characters that show high correlation with the trait (Sugama et al., 1992). Several previous studies (Goswami et al., 1986; Huang et al., 1990; Lester, 1983) have examined the subject in *Penaeus merguensis P. penicullatus, P. vannamei* and *P. stylyrostris* with varying results. In the tiger shrimp, *P. monodon,* Sugama *et al*. (1992) have studied similar subject and recommended that the six segment depth as good indicator for the tail weight. It should be noted however, the samples used by Sugama *et al* (1992) were wild stocks which the supply in the future, due mainly to fishing pressure, will be limited. In response to this situation, efforts to produce brood stocks from farming practices are increasing. However, it is not known whether the trait which was found to be good estimator for tail weight in wild stock can be applicable when selecting individual as brood stock candidate aiming at improving tail weight from population grown in farming conditions.

This paper was aimed to describe the patterns and the amount of morphometric variations within and between the three farmed stocks, and to explore the morphometric traits that may serve as the best estimators for increasing tail weight in selective breeding program.

MATERILAS AND METHODS

Sample collection

Three populations of farmed tiger shrimp derived from brood stock originated from the Aceh, Cilacap and Sumbawa waters were collected. The three populations were sampled from semi-intensive brackish water growing ponds in Langsa (East Aceh), Indramayu (West Java), and Bali for Aceh, Cilacap and Sumbawa stocks, respectively. Although the last two stocks were not sampled from the same area as their brood stocks origin, maximal efforts have been made to ensure that they were descendents of those brood stocks. Two hundreds individuals from each location were sampled and measured for morphometric variability in 22 morphometric traits as described by Dall (1957) and Lester (1983) (Table 1). Except for weight-related traits which were measured using a balance, and body-circumference measures which were measured using a the remaining traits were measured using caliper.

DATA ANALYSES

Comparison of coefficient of variation

As interstock analyses of morphometric variation may be confounded by the presence of intersex differences within the respective stock, a preliminary analysis examining the presence of this phenomenon was undertaken. Depending on the result of this preliminary analysis, interstock analyses may be conducted using separate or combined sexes. In case no differentiation between male and female is found, further analyses are conducted by treating the whole data within each stock as a single data set. Conversely, separate analyses for each sex are conducted, when differentiations in morphometric traits between males and females are detected. The preliminary analysis was conducted using procedure of multivariate analysis of covariance (MANCOVA).

Table 1. Description of 22 Morphometric Trait.

No.	Traits	Description	Ref
1	Partial carapace length (PCL)	Distance from the orbital tip to the posterior of the carapace	1
2	Carapace width (CW)	Widest distance at the last rostral teeth	1
3	Carapace depth (CD)	The highest distance between the top and the base of the carapace	1
4	First segment length (FL)	Distance between carapace posterior margin and posterior margin of the first segment	1
5	Second segment length (SL)	Distance from the posterior margin of the first segment to the posterior margin of the second segment	1
6	Third segment length TL)	Distance from the posterior margin of the second to the posterior margin of the third segment	1
7	Fourth segment length (FL)	Distance from the posterior margin of the third segment to the posterior margin of the third segment	1
8	Anterior abdominal circumference (AAC)	Circumference at the intersection between the second and the third segments	1
9	Second segment abdominal depth (SD)	depth at the intersection between the second and the third segment	1
10	Fifth segment length (FSL)	Distance from posterior of the fourth segment to the posterior margin of the fifth segment	1
11	Sixth segment length (SSL)	Distance from posterior of the fifth segment to the posterior margin of the sixth segment	1
12	Posterior abdominal circumference (PAC)	Circumference at the intersection between the fifth and the sixth segment	1
13	Sixth segment length	Distance from posterior margin of the fifth segment to	1
14	Total length	Distance from the tip of the rostrum to the tip of the telson	2
15	Partial length	Distance from the carapace posterior to the end of exopod	2
16	Rostrum length (RST)	Distance from median posterior margin to the rostrum tip	2
17	Prosertema (PST)	Distance from the tip to the base of prosertema	2
18	Exopod (EXP)	Distance from the tip to the base of exopod	2
19	Endopod (END)	Distance from the tip to the base of the endopod	2
20	Telson (TLS)	Distance from the tip to the base of the telson	2
21	Tail weight (TAW)	Weight of abdomen severed along the carapace posterior	2
22	Total weight (TOW)	Total weight of the whole body	2

Notes: Reference; 1: (Lester, 1983) 2: (Dall, 1957)

Morphometric variability was expressed as coefficient of variation (CV), namely an entity obtained by dividing the standard deviation by the mean and multiplied by 100 (Lewontin, 1966). This was meant to eliminate the possible biases resulted from differences in body size among stocks (Haldane, 1955). The CVs were analyzed in two complementary ways; descriptive, graphical presentation and significant tests as described by Lewontin (1966), Bader and Lehmann (1965) Sokal and Braumann (1980). While the former analysis displays general patterns in both between-stock and among-trait variability profile, the latter quantifies and tests for statistical significance of any differences in CV both between stocks and between traits.

Identification The Best Estimators For The Tail Weight

Determination of morphometric traits which may serve as the best estimators for the tail weight were conducted using coefficient correlation analysis. Within each stock, every trait was correlated against each other. Further, the data were subjected to multiple stepwise regression analysis by assigning tail weight as dependent variable and the other traits as independent variables. The best estimator can be recognized from those with the highest values of determination coefficient (R^2).

RESULTS

Preliminary analyses (results not shown) suggest that sexual dimorphisms were not detected in all stocks of farmed tiger shrimp investigated. Hence, the following results were obtained from the analyses treating the data set for each stock as a single data set irrespective of its sexual composition (proportion of male and female).

Among-traits and Amon- stocks Variability

The pattern of variability profile among traits in the three stocks examined appeared to be similar in that most traits showing less variability in one stock also showed less variability in the others. The most distinct examples for this trend were shown by the total and the tail weight traits. The amount of variability of these traits were the highest in all the three stock investigated.

With respect to the magnitude of variation, Figure 1 shows two types of morphometric traits with highly different magnitude of variation. On one side, there were length-associated traits, those measured with length measurement unit. These traits were low to medium in the magnitude of variation, ranging from 8 to 14 percent. On the other side, there were weight associated traits, i.e. those measured in weight unit (gram). In contrast to the length associated traits, they showed high levels of variations ranging from 27 to 35 percent. The magnitude of morphometric variations in the latter type were double relative to those observed in the length-associated traits.

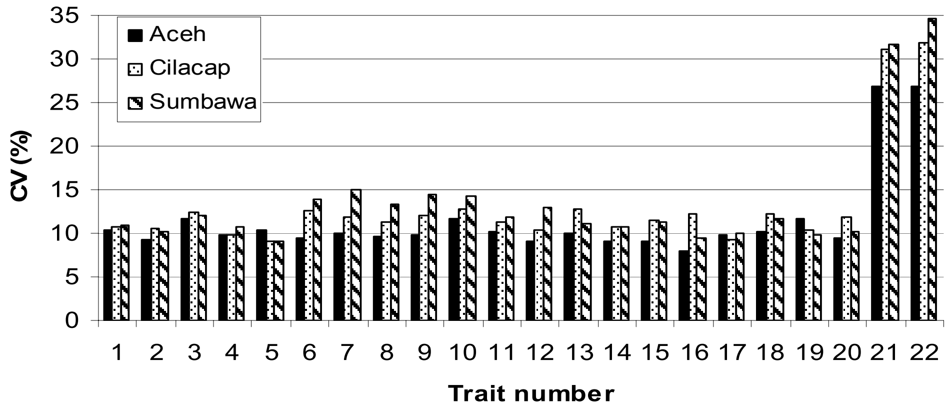

Figure 1. Variability Profile Expressed as CV Of 22 Morphometric Traits Across Three Stocks of Farmed Tiger Shrimp. Trait Numbers Represent Morphometric Traits as Described in Table 1.

Table 2. Summary of Significant Tests for 22 Morphometric Characters in Three Stocks of Farmed Tiger Shrimp.

No	Morphometric trait	1 vs 2	1 vs3	2 vs 3	F table	
					α=0.05	α=0.01
1	Partial carapace length (PCL)	1.07	1.11	1.03	1.26	1.39
2	Carapace width (CW)	1.29*	1.21	0.94	1.26	1.39
3	Carapace depth (CD)	1.12	1.08	0.96	1.26	1.39
4	First segment length (FSL)	0.98	1.16	1.18	1.26	1.39
5	Second segment length (SSL)	0.75	0.77	1.02	1.26	1.39
6	Third segment length (TSL)	1.79*	2.19**	1.22	1.26	1.39
7	Fourth segment length (FSL)	1.42**	2.32**	1.63**	1.26	1.39
8	Anterior abdominal circumference (AAC)	1.37**	1.94**	1.41**	1.26	1.39
9	Second segment abdominal depth (SSAD)	1.53**	2.19**	1.43**	1.26	1.39
10	Fifth segment length (FSL)	1.18	1.46**	1.24	1.26	1.39
11	Sixth segment length (SSL)	1.22	1.34*	1.10	1.26	1.39
12	Posterior abdominal circumference (PAC)	1.30*	2.05**	1.58**	1.26	1.39
13	Sixth segment depth (SSD)	1.61**	1.25	0.78	1.26	1.39
14	Total length (TOL)	1.38*	1.36*	0.98	1.26	1.39
15	Partial length (PTL)	1.59**	1.56**	0.98	1.26	1.39
16	Rostrum length (RST)	2.31**	1.36**	0.59	1.26	1.39
17	Prosertema (PST)	0.87	1.03	1.18	1.26	1.39
18	Exopod (EXP)	1.45**	1.32*	0.91	1.26	1.39
19	Endopod (END)	0.77	0.71	0.92	1.26	1.39
20	Telson (TLS)	1.56**	1.16	0.74	1.26	1.39
21	Tail weight (TAW)	1.34*	1.39**	1.04	1.26	1.39
22	Total weight (TOW)	1.42**	1.66**	1.18	1.26	1.39

Note: 1, 2, and 3 indicate populations of Aceh, Cilacap and Sumbawa, respectively. Single (*) and double asterisks (**) indicate statistical significant levels at α=0.05 and α=0.01, respectively. The values of F table were obtained using degree of freedom 199 and 199.

With several exceptions, the magnitude of morphometric trait variation in the sample, ordered form the lowest to the highest was Aceh, Cilacap and Sumbawa. Between-stock variations were observed in most of the traits (Figure 1.) However, further analysis showed that not all differences found in between-stock comparisons were statistically significant as can be seen in Table 2. In comparisons between the Aceh and the Cilacap, the Aceh and the Sumbawa and between the Cilacap and the Sumbawa, it was found that only 64, 59, and 18 percent were statistically different. The table also shows that the most considerable differences occurred in comparison between the Aceh and the Cilacap and between the Aceh and the Sumbawa stocks. This was supported by not only the number of traits but also by the level of statistical significances.

There was a slight among-stocks variation in the types of independent variables which showed the highest correlation with the tail weight as dependent variable. While in the Aceh and Cilacap stocks, the partial length had the highest correlation with the tail weight with correlation coefficient (r) were 0.94 and 0.85, respectively (Table 3), in the Sumbawa stocks it was the endopod that had the highest correlation with the tail weight (r=0.87) (Table 4). A similar pattern of correlation was also reflected in the coefficient determination values (R^2) where the above mentioned traits showed the highest contribution in explaining the variation in the tail weight (Table 5).

Table 3. Matrices of Coefficient Correlation of 22 Morphometric Traits in the Aceh Stock (Below Diagonal) and the Cilacap Stock (Above Diagonal). Abbreviations Refer to the Morphometric Trait as Described in Table 1.

	PCL	CW	CD	RST	PST	FL	SL	TL	FL	FSL	SSL	SD	SSD	AAC	PAC	OL	PLT	TLS	EXP	END	TAW
PCL		0.90	0.88	0.75	0.85	0.88	0.93	0.92	0.83	0.84	0.77	0.91	0.86	0.89	0.91	0.87	0.04	0.94	0.69	0.48	0.83
CW	0.47		0.86	0.65	0.79	0.86	0.89	0.89	0.65	0.80	0.68	0.85	0.79	0.84	0.86	0.81	0.88	0.89	0.67	0.46	0.78
CD	0.32	0.71		0.68	0.80	0.83	0.87	0.87	0.79	0.78	0.71	0.85	0.77	0.84	0.86	0.83	0.88	0.84	0.63	0.43	0.80
RST	0.27	0.51	0.39		0.69	0.67	0.68	0.69	0.66	0.65	0.67	0.71	0.63	0.71	0.71	0.71	0.73	0.76	0.52	0.39	0.65
PST	0.41	0.91	0.66	0.60		0.78	0.81	0.80	0.73	0.74	0.68	0.78	0.74	0.87	0.86	0.78	0.83	0.83	0.64	0.48	0.74
FL	0.50	0.87	0.50	0.44	0.85		0.93	0.89	0.61	0.83	0.72	0.87	0.81	0.83	0.84	0.81	0.89	0.86	0.63	0.49	0.78
SL	0.50	0.85	0.62	0.46	0.82	3.88		0.93	0.85	0.85	0.75	0.90	0.84	0.87	0.89	0.85	0.94	0.90	0.66	0.52	0.81
TL	0.50	0.87	0.72	0.48	0.86	0.85	0.87		0.86	0.85	0.75	0.91	0.84	0.88	0.90	0.86	0.93	0.90	0.70	0.49	0.82
FL	0.49	0.91	0.69	0.49	0.85	0.84	0.86	0.88		0.78	0.66	0.84	0.75	0.81	0.83	0.80	0.86	0.84	0.61	0.47	0.76
FSL	0.49	0.81	0.54	0.44	0.79	0.78	0.77	0.81	0.79		0.69	0.84	0.77	0.77	0.80	0.75	0.84	0.82	0.61	0.45	0.74
SSL	0.53	0.82	0.57	0.47	0.81	0.81	0.82	0.83	0.80	0.79		0.74	0.71	0.70	0.70	0.71	0.77	0.74	0.50	0.36	0.69
SD	0.47	0.89	0.66	0.50	0.85	0.84	0.77	0.85	0.84	0.75	0.80		0.86	0.89	0.91	0.87	0.93	0.87	0.66	0.46	0.83
SSD	0.49	0.87	0.64	0.47	0.88	0.80	0.80	0.83	0.81	0.75	0.82	0.84		0.81	0.82	0.78	0.85	0.82	0.62	0.44	0.75
AAC	0.47	0.87	0.72	0.50	0.84	0.80	0.76	0.83	6.79	0.67	0.73	0.92	0.80		0.93	0.83	0.90	0.85	0.65	0.50	0.82
PAC	0.36	0.86	0.67	0.43	0.86	0.80	0.80	0.82	0.81	0.74	0.70	0.81	0.83	0.85		0.85	0.92	0.88	0.67	0.41	0.84
TOL	0.48	0.93	0.69	0.61	0.95	0.91	0.88	0.90	0.89	0.81	0.85	0.89	0.59	0.87	0.88		0.89	0.85	0.64	0.44	0.78
PTL	0.46	0.93	0.69	0.59	0.92	0.89	0.89	0.88	0.87	0.81	0.86	0.90	0.88	0.88	0.86	0.97		0.91	0.67	0.47	0.85
TLS	0.44	0.85	0.58	0.47	0.88	0.82	0.77	0.83	0.80	0.78	0.81	0.77	0.84	0.72	0.81	0.86	0.83		0.69	0.47	0.80
EXP	0.42	0.86	0.67	0.53	0.90	0.86	0.81	0.83	0.81	0.76	0.76	0.81	0.85	0.78	0.86	0.90	0.90	0.82		0.33	0.60
END	0.41	0.82	0.59	0.54	0.89	0.83	0.81	0.79	0.75	0.77	0.77	0.75	0.84	0.73	0.80	0.88	0.86	0.86	0.85		0.41
TAW	0.41	0.93	0.74	0.51	0.87	0.85	0.84	0.85	0.86	0.71	0.76	0.91	0.83	0.91	0.87	0.93	0.94	0.77	0.84	0.80	

DISCUSSION

Profile of among-trait and between-stock variability

With respect to phenotypic expressions, it is accepted that they are produced from a combined effects of genetic, environments, and interaction of both (Tave, 1986). From environmental point of view, the Aceh, Cilacap, and Sumbawa stocks used in the current study came from growing ponds applying a semi-intensive management in their production system. Other than this, no data on measurable environmental parameters were available. Given this situation, it is not possible to conclude whether they are considered to be variable or similar. Conversely, different situation occurred for genetic factor. Previous study (Imron *et al*., 1999) showed that the three stocks had slightly different levels of genetic variation. The levels in descending order were Cilacap, Aceh, and Sumbawa. When morphometric data obtained in the current study were combined with the genetic data obtained previously (Imron et al., 1999), an interesting pattern of relationship was observed. In general, stock with high level of morphometric variation as occurred with the Sumbawa stock was characterized by low level of genetic variation, and vice versa. This pattern seems similar to the results of other study (Soewardi *et al.* unpublished) who found that variation of morphometric characters in the base population was higher than those observed in the selected populations. Conversely, genetic variation as measured by mitochondrial cytochrome oxidase I (*mtCOI*), were higher in the selected populations relative to the base populations. Despite acknowledging possible environmental effects, this phenomenon suggests the presence of genetic factor in determining structure of variability in morphometric traits including the growth-related traits such as body weight.

Table 4. Matrix of Coefficient Correlation of 22 Morphometric Traits in the Sumbawa Stock. Abbreviations Refer to the Morphometric Trait as Described in Table 1.

	PCL	CW	CD	RST	PST	FL	SL	TL	FL	FSL	SSL	SD	SSD	AAC	PAC	OL	PLT	TLS	EXP	END
CW	0.72																			
CD	0.78	0.82																		
RST	0.59	0.65	0.62																	
PST	0.60	0.63	0.59	0.57																
FL	0.49	0.34	0.56	0.42	0.45															
SL	0.70	0.77	0.76	0.65	0.64	0.56														
TL	0.75	0.85	0.81	0.66	0.63	0.55	0.80													
FL	0.77	0.81	0.79	0.65	0.65	0.56	0.77	0.90												
FSL	0.53	0.60	0.57	0.57	0.52	0.40	0.66	0.54	0.49											
SSL	0.68	0.72	0.69	0.54	0.58	0.42	0.63	0.73	0.76	0.47										
SD	0.77	0.84	0.79	0.67	0.61	0.54	0.79	0.83	0.83	0.60	0.75									
SSD	0.79	0.83	0.83	0.68	0.64	0.56	0.79	0.80	0.81	0.75	0.72	0.83								
AAC	0.80	0.84	0.88	0.68	0.64	0.56	0.80	0.86	0.86	0.62	0.75	0.89	0.89							
PAC	0.67	0.73	0.76	0.60	0.56	0.51	0.72	0.74	0.74	0.54	0.67	0.78	0.76	0.82						
TOL	0.81	0.87	0.85	0.78	0.70	0.57	0.83	0.86	0.86	0.67	0.76	0.87	0.88	0.90	0.78					
PTL	0.81	0.88	0.86	0.73	0.70	0.57	0.83	0.87	0.37	0.66	0.77	0.89	0.88	0.92	0.79	0.95				
TLS	0.63	0.66	0.66	0.54	0.55	0.42	0.63	0.64	0.65	0.49	0.57	0.68	0.72	0.72	0.63	0.70	0.71			
EXP	0.78	0.82	0.77	0.66	0.64	0.53	0.76	0.78	0.79	0.59	0.68	0.81	0.81	0.84	0.64	0.87	0.88	0.63		
END	0.68	0.75	0.70	0.61	0.66	0.46	0.61	0.66	0.69	0.53	0.62	0.69	0.71	0.75	0.62	0.80	0.80	0.60	0.78	
TAW	0.75	0.82	0.80	0.63	0.63	0.51	0.58	0.74	0.77	0.53	0.67	0.80	0.79	0.85	0.73	0.85	0.86	0.65	0.76	0.87

Table 5. Contribution of Several Morphometric Traits in Explaining Tail Weight Variation (R^2) Assessed Using Multiple Regression Analysis.

Stock	Morphometric traits	R^2
Aceh	Partial length	87.85
	Partial length, anterior abdominal circumference	91.07
	Partial length, anterior abdominal circumference, carapace width	92.31
Cilacap	Partial length	73.01
	Partial length, posterior abdominal circumference	73.95
	Partial length, carapace depth, posterior abdominal circumference	75.55
Sumbawa	Endopod	74.77
	Endopod, anterior abdominal circumference	83.87
	Endopod, anterior and posterior abdominal circumference,	85.38

From the perspective of genetic improvement programs, particularly those applying conventional selective breeding, high variation in body weight means that possibility to improve this trait is more likely. Hence both the total weight and tail weight are potential to be genetically improved. However, it should be noted that this is only rough prediction, since further studies on the proportion and the types of genetic component accounted for that variation (heritability) need to be explored.

Estimators for the Tail Weight

The emergence of partial length a single best estimator for tail weight in the population of Aceh and Cilacap was easy to understand since the trait refers to the same target as measured by the tail weight. While the tail weight was measured using weight unit after killing the animal, the partial length measures the same target in length unit and can be conducted without killing the animal. Similar explanation holds for both the anterior and posterior abdominal circumferences, which in combination come along with the partial length. Hence, it is not quite clear why the endopod instead of the partial length that explain most of the variation in tail weight in the Sumbawa stock. The partial length itself came as the second trait explaining most of the variation in tail weight.

The results observed in the current study showed some similarity to as well as differences from those obtained by previous studies such as Huang et al. (1990), Lester (1983) and Sugama et al.(1992). While Huang et al. (1990) working on *Penaeus penicullatus* found that the best estimators for the weight were partial length and posterior abdominal circumference for females and partial length and anterior abdominal circumference for males, Lester (1983) working on other species, *P. vannamei* and *P. stylirostris* found that the six segment depth had highest correlation with the tail weight. Study in *P. monodon* conducted by Sugama *et al*. (1992) found that the carapace and the partial lengths and the six segment depth were the best estimators for the tail weight. A slight variation observed between the results of the current study from those obtained previously, particularly in the same species as one conducted by Sugama et al (1992) may be explained by differences in the size of the sample. While Sugama's *et. al*. (1992) study used tiger shrimp samples of 45 to90 gram in size, the current study used much smaller sizes, ranging from 21 to 25 grams. This difference is potential to cause variation in estimator traits for the tail weight, particularly when allometric relationships characterize growth of the animals at different sizes. This is supported by Chow and Sandifer (1991) who found that average tail range ratio and average condition factor were lower in younger age group relative to those in older group. Given these facts, determination which trait to measure when selecting brood stock candidates for improved tail weight, should be conducted cautiously, in that size range of individuals at the time of selection need to be considered.

Despite these variations, it appeared that there was a trait which consistently showed high correlation with the tail weight in both the farmed and the wild stocks of tiger shrimps, namely the partial length. Given this consistency as well as easy to measure, the trait can be used as a good indicator when selecting brood stock candidate to be used in breeding program aiming at improving the tail weight.

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