Identifying *Penaeus merguiensis* de Man, 1888 stocks in Indonesian Fisheries Management Area 573: a truss network analysis approach

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Abstract. Banana shrimp (*Penaeus merguiensis* de Man, 1888) is a high valuable penaeid shrimp which occurs widely in Fisheries Management Area (FMA) 573 of Indonesia. Until now there is no report on stock structure of banana shrimp in the area. This study was aimed to identify stock structure of the banana shrimp based on morphometric characters using truss network analysis. The shrimps were collected from four locations, namely Pangandaran, Cilacap, Kebumen, and Kupang. A total of 295 shrimps were used in the analysis. The analysis was constructed by interconnecting 19 landmarks to form a total of 43 distance variables extracted from sample digital images using tps Dig2 and PAST software platforms. The transformed truss measurements were subjected to factor analysis and classification by cross-validation of discriminant analysis. The results of factor analysis showed a significance first factor is a variable that describes one part of the body from the rostrum bottom until the fifth segment of the abdomen and second factor describes the rostrum upper sixth segment of shrimp and shrimp body. Canonical variance analysis revealed two stock units of banana shrimp in FMA 573. Discriminant analysis indicated the analyzed data for grouping of four populations are able to represent the group of the actual population. Based on this finding, it is recommended to restructure the FMA 573 into two management areas, i.e. southern part of Java and Bali, and south Nusa Tenggara including Sawu Sea and west part of Timor Sea.
Key Words: banana shrimp, crustacean fishery, Indian Ocean, morphology characters, Penaeidae.

Introduction. In fishery point of view, Indonesia is rich of valuable crustacean resources with relatively high demand in local, regional and global market, such as mud crab, blue swimming crab, hippoid crab, lobster, mantis shrimp, penaeid shrimps, crayfish, etc. Among them, there are current numerous studies in Indonesian crustaceans, such as mud crab (Tahmid et al 2015a, b), blue swimming crab (Prabawa et al 2014; Zairion et al 2014; Hamid & Wardiatno 2015; Hamid et al 2015a, b; Zairion et al 2015a, b; Hamid et al 2016a, b, c, d; Zairion et al 2016), hippoid crabs (Mashar & Wardiatno 2013a, b; Sarong & Wardiatno 2013; Mashar et al 2014; Wardiatno et al 2014; Ardika et al 2015; Mashar et al 2015; Muzammil et al 2015; Santoso et al 2015; Wardiatno et al 2015a, b; Edritanti et al 2016; Mashar & Wardiatno 2016; Wardiatno et al 2016a; Pramithasari et al 2017), lobster (Wahyudin et al 2017a, b; Wahyudin et al 2016; Wardiatno et al 2016b, c, d), mantis shrimp (Wardiatno 2012, 2014; Wardiatno & Mashar 2010, 2011, 2013; Wardiatno et al 2012), but only few about crayfish (Patoka et al 2016) and penaeid shrimp (Saputra et al 2013).

Banana shrimp (*Penaeus merguiensis* de Man, 1888), one of economical penaeid shrimps, is widely distributed in the western part of the Indo-Pacific from the Persian Gulf up to Thailand, Hong Kong, the Philippines, Indonesia, Papua New Guinea, New Caledonia and Northern Australia (Phongdara et al 1999; Chu et al 2003; Wanna et al 2004; Aziz et al 2009; FAO 2017). In terms of fishery, Indonesian territory is divided into 11 Fishery Management Area (FMA), and the banana shrimp can be found in most FMA except in FMA 713 and 714 (Suman et al 2014). According to Ministry of Marine Affairs and Fishery Decree no. 47/2016 the utilization level of the penaeid shrimps (including the banana shrimp) is over-exploited, except in FMA 717 (Pacific Ocean). Subdivision of 11 FMA are based on similarity in characteristics and dynamics of the waters as well as its coverage area, so-called eco-region (Prof. Indra Jaya 2017, personal communication), but are not based on stock boundaries. In fact, stock base subdivision would be more practical and helpful for sustainable and effective management in fishery resources (Begg et al 1999).

Stock and the population are often interpreted as the same thing; leading to the use of these two terms are becoming confusing. In general, the stock is defined as a portion of population or a subpopulation at a particular location. A group of individuals of the same species or subspecies that are spatially, genetically, or demographically separated from other groups is the difinition of population (Wells & Richmond 1995). Fishery scientists distinguish fishery stocks and the population more definitely, that the stock owns an archetype of migration and particular spawning sites. Stock more leads to abundance and management of fishery resources. Effendie (1979) defines stock as a population or part of the population in which all members are characterized by certain characters that cannot be inherited, but they are most likely influenced by the environment; a group of specific species that are exploited in a certain area or a certain way (Smith et al 1990). In addition, Sparre et al (1989) stated that the stock is a group of individuals or a member of a species that has the same characters and occupying a certain geographical area.

In fisheries management philosophy, if there is more one stock in FMA each stock must be managed separately to optimize their catch (Grimes et al 1987). Identification of the stock is a way to obtain information about the condition of the stock. It is needed for the most part to maintain a balance between utilization and conservation. According to Thorpe et al (1995) stock identification is a prerequisite in fisheries management, at the same time as population structure is considered a fundamental component of conservation biology. Several methods for identifying stocks are available, such as based on their population parameters, physiological characters and behaviour, meristic and morphometric, calcareous characters, cytogenetic and biological marker, and otolith (Ihssen et al 1981; Swain et al 2005; Cadrin et al 2005, 2014).

Analysis of morphometric diversity is one of the most frequently used methods to identify stocks with fairly low cost (Cadrin 2005). Morphometric variance between the stocks of a species can be used as a basis in determining the structure of the stock since it is easier to be done and learned in a short time (Begg et al 1999). Currently truss networking system has been developed as a new system for morphometric measurement (Sathianandan 2003; Cadrin et al 2005, 2014). Morphometric identification with truss network systems constructed with the help of landmark points are proved to be effective and powerful tools for capturing information about the shape of an organism and for stock identification (Strauss & Bookstein 1982; Cavalcanti et al 1999; Sathianandan 2003). This method is used to improve the traditional methods to identify the stock (Turan 1999; Akbarzadeh et al 2009; Sajina et al 2011; Sen et al 2011; Remya et al 2014; Pazhayamadom et al 2015).

In Indonesia, research on stock of a fishery resource in connecting with FMA is rarely done. In banana shrimp case, it is stated that the penaeid shrimp in FMA 573 is categorized as over-exploited in Ministry of Marine Affairs and Fishery Decree no. 47/2016. However, the number of unit stocks in the area has not been assessed. In fact, as mentioned above, the biological information on unit stocks is needed for better management. The study was aimed to reveal the unit stock of banana shrimp in FMA 573. The results can be a recommendation for stakeholders to restructure the subdivision of the area.

Material and Method

Description of the study sites. Sampling collections were conducted in FMA 573 covering Pangandaran, Cilacap, Kebumen, and Kupang (Figure 1). Detail of sampling location and time is presented in Table 1. Morphometric and meristic analysis were performed at the Fish Biology Laboratory of the Marine Fisheries Research Institute in Jakarta, Indonesia.

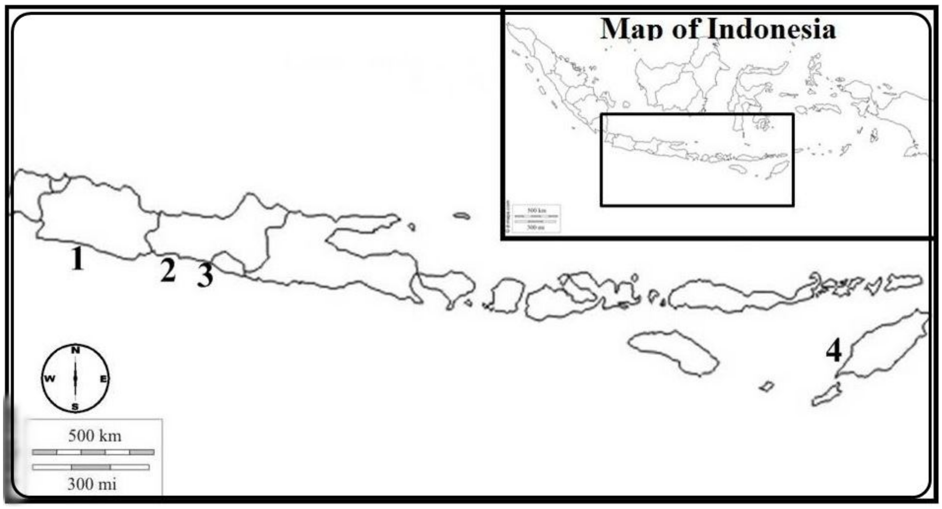

Figure 1. Sampling locations of the banana shrimp (*Penaeus merguiensis* de Mann 1888), as indicated by numbers (1 = Pangandaran, 2 = Cilacap, 3 = Kebumen, 4 = Kupang).

Table 1
The location, sample number, sampling site GPS position, and time of sample collection

Location	*No. of sample*	*Latitude*	*Longitude*	*Sampling time*
Pangandaran	95	S 07°37'.166"	E 108°45'.926"	Jul and Dec 2016
Cilacap	63	S 07°43'.737"	E 109°01'.417"	Jul and Nov 2016
Kebumen	70	S 07°43'.228"	E 109°23'.651"	Aug and Nov 2016
Kupang	67	S 10°8'.27.856"	E 123°36'.0.354"	Oct and Dec 2016

Shrimp collection. Shrimp specimens were obtained from the fish landing, while the specimens were caught by local fishermen using trammel net. The collected shrimps were placed in a jar, and preserved with 70-96% alcohol prior to laboratory works.

Sample digitizing. Prior to digitizing, shrimp samples were first cleaned in running water, dried and placed on a flat platform with vertical and horizontal grids. The distance between the vertical and horizontal grids was defined as one square unit covers the area of one cm^2 for calibrating the final stages of image processing and data accuracy. Each individual shrimp was labelled with a specific code to identify the picture. For individual image digitizing shrimp, a series of digital cameras Sony Cybershot DSC H300 was mounted on a tripod. After the shooting process was completed, the shrimp sample was observed for its sex and if the sex could not be determined, disecting on reproduction organ was carried out (Balasubramanian & Natarajan 2000).

Truss morphometric data measurements. In this research morphometric characters was analyzed the structure of the stock in banana shrimp using truss network analysis. Nine-teen landmark points were determined (Table 2), and from the 19 points was obtained 43 variables landmark truss network. Forty three (43) variables are formed following the formula of Strauss & Bookstein (1982). To ensure whether there are differences between the four populations, multivariate analysis of variance (MANOVA) was performed. A linear combination of two software program, namely tpsDig2 V 2.1

(Rohlf 2006) and paleontological Statistics (PAST) (Hammer et al 2001) was used to retrieve data from the morphometric image of each specimen. All images were first converted from JPEG (*.jpg) format to TPS (*.tps) using utility programs, tpsUtil V1.38 (Rohlf 2006). Data description tps image file format of tpsDig used as the input source in the PAST and the data on the distance between the coordinate was extracted. The result of morphometric truss network system was presented in Figure 2 (Rebello et al 2013; Munasinghe 2014).

Table 2

Landmarks for extract measurements of truss in *P. merguiensis* collected from four locations in Indonesian Fisheries Management Area 573, i.e. Pangandaran, Cilacap, Kebumen, and Kupang

Number of landmark	*Position of landmark*
1	Base of the rostrum
2	The upper teeth the first rostrum
3	The upper of the first segment base
4	The upper of the second segment base
5	The upper of the third segment base
6	The upper of the fourth segment base
7	The upper of the fifth segment base
8	The upper of the sixth segment base
9	The upper of the final segment base
10	Caudal base
11	End of the sixth segment bottom
12	End of the fifth segment bottom
13	End of the fourth segment bottom
14	End of the third segment bottom
15	End of the second segment bottom
16	End of the first segment bottom
17	The base of the first walk leg
18	The base of the antenna
19	The base of carapace

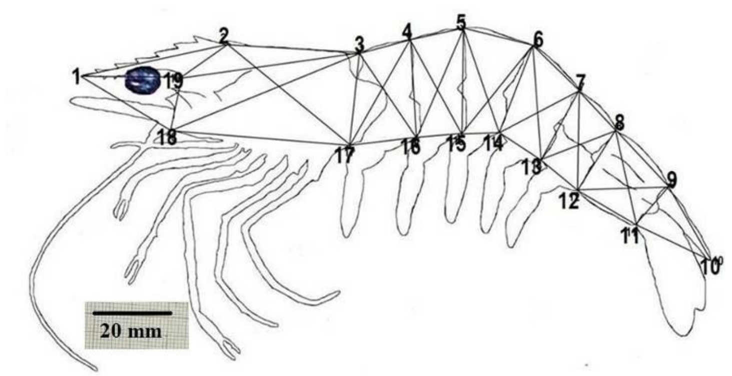

Figure 2. Position of truss network and conventional dimensions measured for initial regression analysis in the banana shrimp (*Penaeus merguiensis*) collected from four locations in Indonesian Fisheries Management Area 573, i.e. Pangandaran, Cilacap, Kebumen, and Kupang.

***Data analysis**.* All of truss measurement were transformed, tested for their normalities and outliers and if the outliers were recorded, they were removed prior the further analysis as suggested by Jolicoeur (1963), Sen et al (2011), Remya et al (2014) and Pazhayamadom et al (2015). After eliminating the outliers, all selected measurements were 295. Furthermore, the depended size effect was removed by using allometric approach by modifying the formula provided by Ihssen et al (1981), Hurlbut & Clay (1998). Transformation of the measurement data was used the formula as follow:

$$Mtrans = logM - ß(logCL - logCLmean)$$

where: Mtrans is the transformation of the measurement, logM is the natural logaritmic transformation of the original measurements, ß is the regression slope in the group from the log M vs. log CL, CL is the shrimp carapace length, and CLmean is the average shrimp carapace length.

The correlation coefficient between the variables were transformed and shrimp carapace length was recalculated to check whether the data transformation effective in removing the size effect of the data. MANOVA was conducted to examine the significance among different populations. Forty three measurement selected from truss measurement were then analyzed further with factor analysis according to PROC FACTOR of SAS program (Hatcher 2003). Factor analysis of truss measurements was performed to extract information from any location and principal method was used to extract these factors. Only the residual value on the factors will be the subject to the procedure of rotation by varimax (orthogonal) rotation (SAS INSTITUTE 2008). To identify the variables that indicate a high load of a particular component, rotated factors were selected for scratching with the procedure as was described by Hatcher (2003). Then PROC discriminant procedure (SAS 2008) was used for individuals grouping with cross-validation of the discriminant analysis.

Results and Discussion. Most of crustacean morphometric studies were traditionally aimed to establish allometric relationships (Wardiatno & Tamaki 2001; Mashar & Wardiatno 2013a, b; Pramithasari et al 2017), but they were never used in determining stock structure of crustacean resources. However, current method, so-called truss network system has been developed to identify the stock unit in aquatic species (Bemvenuti 2006; Jaferian et al 2010; Cadrin et al 2005, 2014). The method has been applied in penaeid shrimp study (Aktas et al 2006; Rebello 2003). Unlike traditional methods, the truss network system covers the entire body of organisms in the section of a uniform network, and this increases the likelihood the extraction of morphometric differences. Thus this method is much more powerful in elucidation the morphological variety between and among population (Turan 1999). The total number of banana shrimp specimens collected from four research sites at FMA 573 was 295 individuals. Detail information on the collected shrimp is summarized in Table 3.

Table 3

Size, sex ratio and mean carapace length (MCL) of banana shrimp (*P. merguiensis*) from four sampling points of Indonesian Fisheries Management Area 573

Sampling site	*Number of sample*	*Sex*		*Sex ratio (M/F)*	*MCL ± SE (mm)*	
		Male	*Female*		*Male*	*Female*
Pangandaran	95	63	32	1 : 0.51	37.82±0.31	52.49±0.81
Cilacap	63	42	21	1 : 0.50	39.35±0.33	48.37±1.54
Kebumen	70	48	22	1 : 0.46	36.77±0.26	48.16±0.97
Kupang	67	22	45	1 : 2.05	30.32±0.44	38.62±0.59
Total	295					

The results of the MANOVA analysis based on 43 variables indicated that no significant difference was found among the four populations (Wilk's Lamda = 0.047, F = 9.17). Factorial analysis revealed that among significant nine parameters, the first three parameters was able to explain 95% of the total diversity in morphometric characters, with characteristic root values 30.25, 7.35 and the 2.94, respectively. The first factor is a variable reflecting the following truss distance variables: 1-18, 2-17, 3-4, 3-16, 3-19, 4-5, 4-15, 4-16, 4-17, 5-6, 5-14, 5-15, 5-16, 6-7, 6-13, 6-14, 6-15, 7-8, 7-12, 7-14, 8-13, 12-13, 13-14, 14-15, 15-16, 16-17, 17-18, and 18-19. It is characterized by the value loading factor in each of these truss distance variables (Table 4, Figure 3). While the second factor is a variable that explains the truss distance variables of 1-2, 1-19, 8-9, 8-11, 9-11, 9-12 and 11-12 and the third factors as indicators of truss distance variables of 8-12, 9-10 and 17-19.

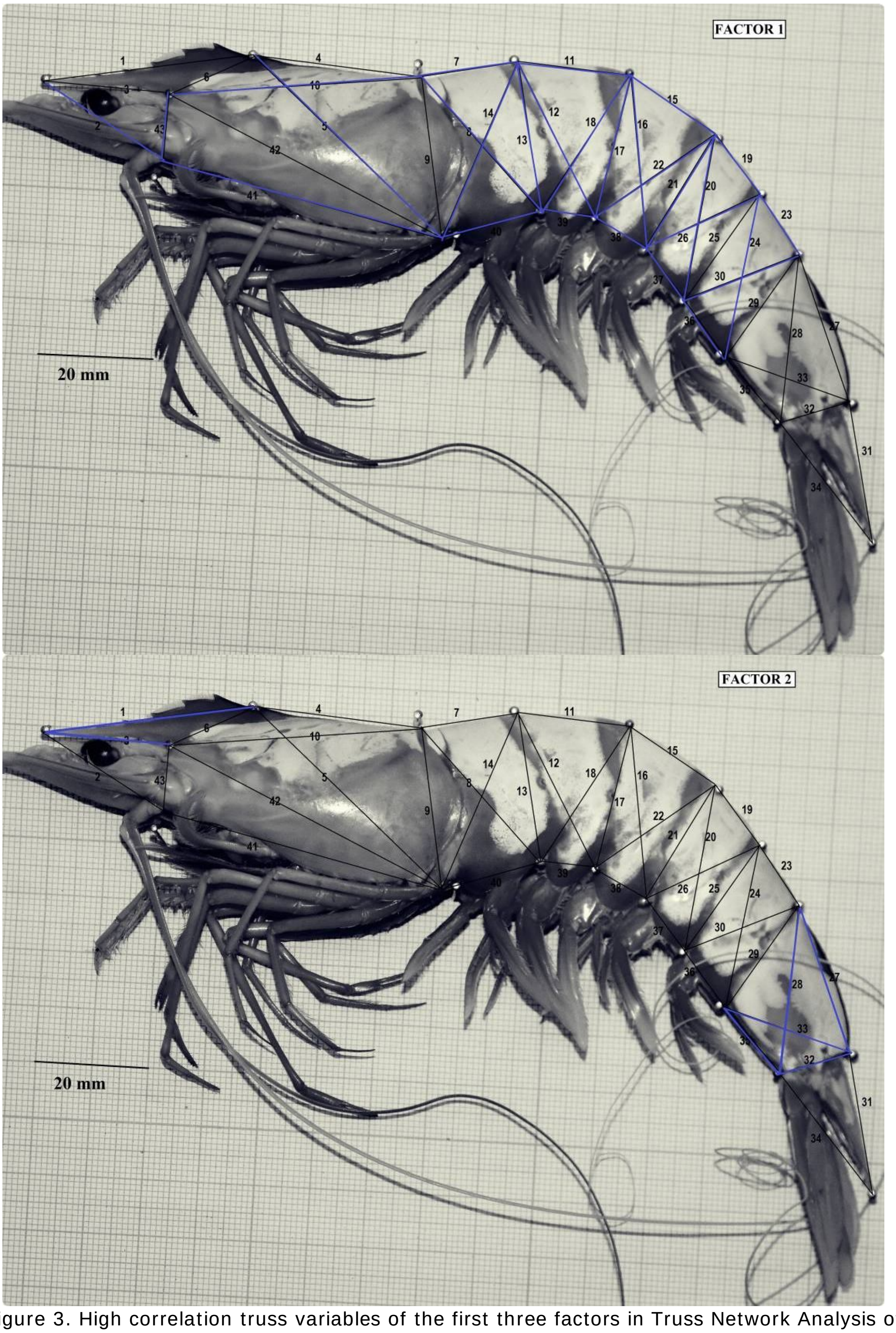

Figure 3. High correlation truss variables of the first three factors in Truss Network Analysis of banana shrimp (*Penaeus merguiensis*) collected from Indonesian Fisheries Management Area 573.

Table 4

Variables for data loading truss of rotation factor

Truss distance	*Factor 1*	*Factor 2*	*Factor 3*	*Truss distance*	*Factor 1*	*Factor 2*	*Factor 3*
1-2	-0.6203	0.77767	0.06658	6-15	-0.9106	-0.3181	-0.0978
1-18	-0.8702	0.41184	0.25113	7-8	-0.8732	-0.3426	0.30922
1-19	0.69235	-0.7102	-0.1107	7-12	0.8664	0.37046	-0.2918
2-3	-0.7867	0.50237	-0.2563	7-13	-0.589	-0.6037	0.45671
2-17	0.85219	-0.3636	0.16549	7-14	-0.942	0.29356	-0.1412
2-19	-0.756	0.16882	-0.5095	8-9	0.67343	0.72568	0.11548
3-4	0.98849	-0.0204	-0.0041	8-11	-0.7153	-0.6837	-0.124
3-16	-0.9749	0.11113	0.0109	8-12	-0.6644	-0.0208	0.6929
3-17	0.75415	0.41427	0.03117	8-13	0.88442	0.31031	-0.3012
3-19	0.80297	-0.4711	0.26275	9-10	-0.0598	0.14723	0.70356
4-5	0.91177	-0.4021	-0.0686	9-11	0.75602	0.64296	0.10772
4-15	-0.9142	0.40089	0.04254	9-12	-0.7099	-0.6927	-0.0973
4-16	0.94915	-0.2958	-0.0496	10-11	0.67834	0.52285	0.142
4-17	-0.9877	-0.0251	-0.0095	11-12	0.72881	0.66877	0.13017
5-6	0.87697	0.40308	0.12255	12-13	-0.8504	-0.3492	0.3478
5-14	-0.8946	-0.3627	-0.1371	13-14	0.95955	-0.1708	0.19538
5-15	0.98688	-0.1137	0.0391	14-15	0.91238	0.37473	0.0877
5-16	-0.9001	0.4259	0.07465	15-16	0.89461	-0.4404	-0.0419
6-7	0.96382	-0.1823	0.14201	16-17	0.9846	-0.1051	-0.0088
6-13	-0.9568	0.24967	-0.1017	17-18	-0.8083	0.46956	0.34199
6-14	0.97601	0.00439	0.15332	17-19	-0.4934	0.03163	-0.6601
				18-19	-0.9502	0.07559	0.21249

In this study the first, second and third factor is a collection of truss distance variables that are correlated, but there is no correlation between factors. This indicates that the size of the shrimp on the truss distance variables of the same factors will have a comparable size change. Variables with a positive score indicate that they will amend in line with the changes the shrimp body, while the variable with a negative score will amend otherwise. From the factor analysis showed that first factor is the variable describing the shrimp body portion from the rostrum to the bottom of the fifth segment of the shrimp body as a whole. The second factor describes parts of shrimp body from the rostrum to the upper sixth segment of shrimp and shrimp abdomen. Third factor only shows the distance from the base of the sixth segment to the bottom of the sixth segment, the distance from the base of the caudal to the end of the caudal, and the distance between the first walk legs to the base of the rostrum.

To discriminate shrimp populations in four sampling points, canonical variance analysis using the morphometric characters was conducted by plotting them to the first and second axis. The analysis results revealed that banana shrimp population from Kupang (East Nusa Tenggara) were clearly different from those in South Java (Pangandaran, Cilacap and Kebumen) (Figure 4). It means that banana shrimp in FMA 573 derived from two stocks. Recent study by Sun et al (2013) showed that the population of the east coast of the Indian Ocean and the Pacific Ocean are morphologically almost identical so it is considered as one stock. Study the structure of the stock with morphological approach to shrimp is still very limited, especially in Indonesia. Kusrini et al (2009) studied morphology of banana shrimp and found that there were differences in morphology of banana shrimp among populations in five native habitats. They concluded that the shrimp population were divided into two groups, i.e. the first group is Pontianak, Lombok Strait – Bengkulu, and the second group is the Sunda Strait Cilacap. However, these findings are different from what has been reported from the results of previous studies conducted for the population of tiger shrimp (*Penaeus monodon*) (Rebello 2003; Rebello et al 2013; Munasinghe 2014).

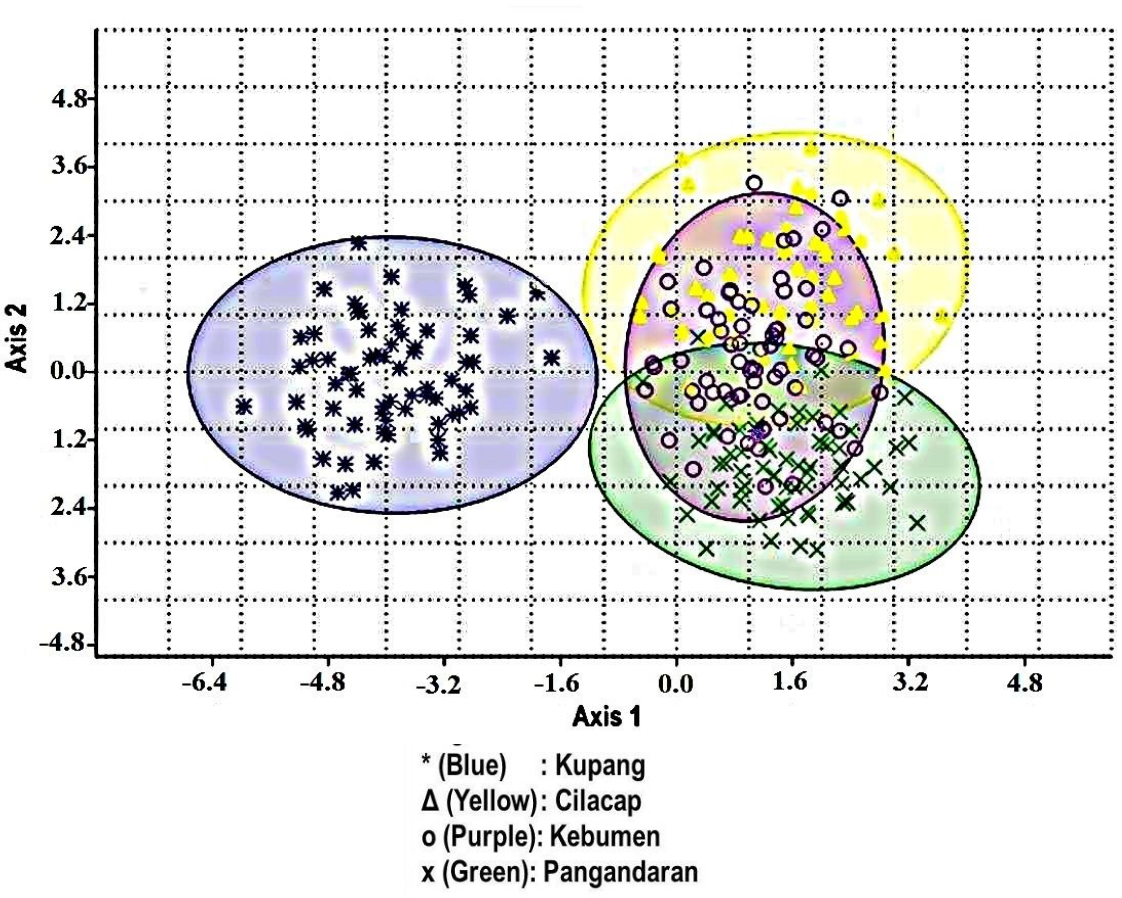

Figure 4. Analysis of the canonical variance on two axes extracted from 43 truss points measurement in banana shrimp (*P. merguiensis*) collected from four locations in Indonesian Fishery Management Area 573, i.e. Pangandaran, Cilacap, Kebumen and Kupang.

Discriminant analysis to find the membership of a particular individual in the population based on 43 banana shrimp truss characters found that the clump percentage of Cilacap and Kebumen banana shrimp was not much different, i.e. 58.73% and 50.75%, respectively, whereas in Kupang and Pangandaran population was 97.01% and 81.43% (Table 5). Almost half of Cilacap shrimp population constructed Kebumen shrimp population, and also half of Kebumen shrimp population is at Cilacap and Pangandaran shrimp population. This indicates the morphological similarities between these three populations. In other way around, shrimp population of Kupang is 97% characterized originally from Kupang. In other words, the morphological structure of Kupang shrimp bears no resemblance to the structure of other shrimp populations of South Java. It is supported by the result of discriminant analysis that 72% sample data used correctly classified the shrimp population and only 28% misclassification. It can be concluded that the data sample used to group four banana shrimp populations has been able to represent the grouping of the actual population. Changes in morphology between populations in different sampling points are probably due to the genetic structures and different environmental conditions. Therefore, animals that have the same morphological characters are often thought to form a single stock and assessments have been used extensively in distinguishing the stock in the fishing industry (Dwivedi & Dubey 2013).

Table 5
Discriminant analysis of shrimp percentage from each sampling point (row) grouped into location (pool)

Location	*Cilacap*	*Kebumen*	*Kupang*	*Pangandaran*
Cilacap	37	21	1	4
Kebumen	14	34	1	18
Kupang	0	1	65	1
Pangandaran	3	9	1	57
Total degree classified (%)	72			
Total degree unclassified (%)	28			
Proportion	0.5873	0.5075	0.9701	0.8143

Conclusions. Banana shrimp (*P. merguiensis*) in Indonesian Fisheries Management Area 573 consisted of two different stocks. It is recommended to restructure the FMA 573 into two management areas, i.e. southern part of Java and Bali, and south Nusa Tenggara including Sawu Sea and west part of Timor Sea. The subdivision of the FMA would help stakeholders to establish methods, strategies or scenarios for sustainable use of the shrimp.

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