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MORPHOMETRIC CHARACTER AND MORPHOLOGY OF ABALONE *Haliotis squamata* REEVE 1864 IN COASTAL SOUTHERN JAVA AND BALI

KARAKTER MORFOMETRIK DAN MORFOLOGI ABALON Haliotis squamata Reeve 1846 DI PESISIR SELATAN JAWA DAN BALI

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ABSTRACT

The standard of measurement of abalone is very important because it can help to identify accurately abalone shellfish based on shell morphology. This research was aimed to examine the truss morphometric and morphologycal characters of *Haliotis squamata* intraspecies in the southern coastal Java and Bali. The research was conducted from December 2014 to August 2016. Abalone was collected based on the purposive sampling method, it was then identified. The shellfish of abalone was measured and analyzed by using principal component analysis (PCA), canonical discriminant analysis and cluster analysis. The results showed that PCA was able to separate *Haliotis squamata* populations from Java and Bali using combination of PCIII and PCIV based on the factor coefficient values. The key characters that separated *Haliotis squamata* from the population of Java and Bali were the combination of characters BF (0.535) for PCIII and characters CH (0.522) for PCIV. Canonical discriminant analysis showed that Bali was the highest sharing component value (100%) of intra population and also the lowest sharing component of inter population (0%). The highest percentage of similarity was 99.91% that indicated the population of Binuangeun and Pangandaran, while the lowest was 99.31% for the population of Banyuwangi and Bali. The morphological characteristics of *Haliotis squamata* species in several locations showed specific characters such as color patterns, textures and shapes.

Keywords: abalone, *Haliotis squamata*, population, morphology, truss morphometric

ABSTRAK

Standar pengukuran dalam identifikasi abalon sangat penting dilakukan untuk membantu identifikasi abalon berdasarkan morfologi cangkang secara akurat. Tujuan penelitian ini adalah untuk mengkaji karakteristik truss morfometrik dan morfologi intraspesies Haliotis squamata di Perairan Selatan Jawa dan Bali. Penelitian dilakukan pada bulan Desember 2014 sampai Agustus 2016. Koleksi sampel dilakukan berdasarkan metode purposive sampling, selanjutnya sampel diidentifikasi. Cangkang abalon diukur dan kemudian kemudian dianalisis menggunakan analisis Principal Component Analysis (PCA), analisis kanonikal diskriminan dan analisis cluster. Hasil PCA menunjukkan bahwa pemisahan populasi Haliotis squamata asal Jawa dan Bali berdasarkan kombinasi PCIII dan PCIV dengan nilai koefisien faktor. Karakter utama yang memisahkan Haliotis squamata dari populasi Jawa dan Bali adalah kombinasi karakter BF (0,535) untuk PCIII dan karakter CH (0,522) untuk PCIV. Analisis kanonikal diskriminan menunjukkan bahwa Bali memiliki nilai sharing component yang tertinggi (100%) untuk intrapopulasi dan juga nilai sharing component terendah (0%) untuk interpopulasi. Persentase similaritas tertinggi adalah 99,91% untuk populasi asal Binuangeun dan Pangandaran, sedangkan yang terendah adalah 99,31% untuk populasi Banyuwangi dan Bali. Karakteristik morfologi spesies Haliotis squamata pada beberapa lokasi menunjukkan ciri khas tertentu seperti pola warna, tekstur dan corak.

Kata kunci: abalon, *Haliotis squamata*, intraspesies, morfologi, truss morfometrik

I. INTRODUCTION

Abalone belongs to the class of gastropods (family of Haliotidae) that live in tropical marine and temperate waters (Gieger, 2000). In Indonesia, abalone can be found in intertidal and subtidal waters (Dharma, 1988; Setyono, 2009). There are around 58 abalone species scattered in the world. (Gieger, 2000). Seven species of them (*H. asinina, H. squamata, H. varia, H. ovina, H. glabra, H. planata* and *H. crebrisculpta*) can be found in Indonesian waters (Dharma, 1988; Geiger, 2000).

In general, identification of abalone based on the morphology of the shell by observed at the color or pattern of colors, shapes, and textures. (Dharma, 1988; Soelistyowati *et al.*, 2013). The morphological character of the shell can be used as a guide for general species identification (Chiu *et al*., 2002). Some abalone morphometric studies that have been carried out include *H. cracherodii* species on the coast of Laguna, California (Tissot, 1988), *H. iris* species in New Zealand (Mcshane *et al*., 1994), *H. squamata* species in Maluku, Indonesia (Uneputtya and Tala, 2011). Previous research shows a lack of character measurement points. Thus there is no consistency in measuring specific morphometric characters.

The standard of measurement in the identification of abalone is very important because it can help identification based on shell morphology accurately. One way to determine the measurement standard is the morphometric truss method. Strauss and Bookstein (1982) states that the morphometric truss method can help describe character shapes (patterns) precisely by comparing the size of the morphological parts between species/populations. In this study, morphometric truss design was carried out to describe sketches or patterns in finding the relationship of line dimensions on abalone shells. Character measurements carried out in this study are based on length and width, as well the sides produced from lines connecting points obtained from lines of length and width.

Scientific information about the characteristics of morphometric and morphological truss in *H. squamata* species has never been done in the Southern Coastal of Java and Bali, Indonesia. The purpose of this study was to examine the characteristics of morphometric truss and morphology of intraspecies *H. squamata* as a standard reference in abalone measurements in Indonesia.

II. RESEARCH METHODS

2.1. Time and Place of Research

The research was conducted from December 2014 to August 2016. Abalone sample collection from Banten Province, West Java Province, East Java Province, and Bali Province. The Bali sample collection is derived from the collaboration of Institute for Mariculture Research and Fishes Extension (IMRAFE) (Figure 1). Morphological analysis of abalone shells was conducted at the Laboratory of Biosystematics and Animal Ecology of Department Biology, Bogor Agricultural University.

2.2. Sampling and Identification

Abalone sampling was carried out based on the purposive sampling method. The total sample collected was 260 individuals with each sample: Banten (n = 182), West Java (n = 59), East Java (n = 9), and Bali (n = 10) (Table 1). Identify samples using the book Identification key shell II (Dharma, 1988).

Table 1. Sample detailed information in each location.

Province	Location	Coordinate		Hose class (mm)		Number of samples
		E	S	Min	Max	
Banten	Binuangeun	105º 53'630'	06º 49, 87,4'	33.41	72.11	182
West Java	Pangandaran	108º 39' 38,1'	07º 42'18,8"	40.02	72.11	59
East Java	Alas Purwo	114º 22' 6,24"	08º 40' 20,4"	40.02	72.11	9
Bali	Negara	114º 38' 22,25"	08º 24' 25,92"	40.02	60.28	10
Total						260

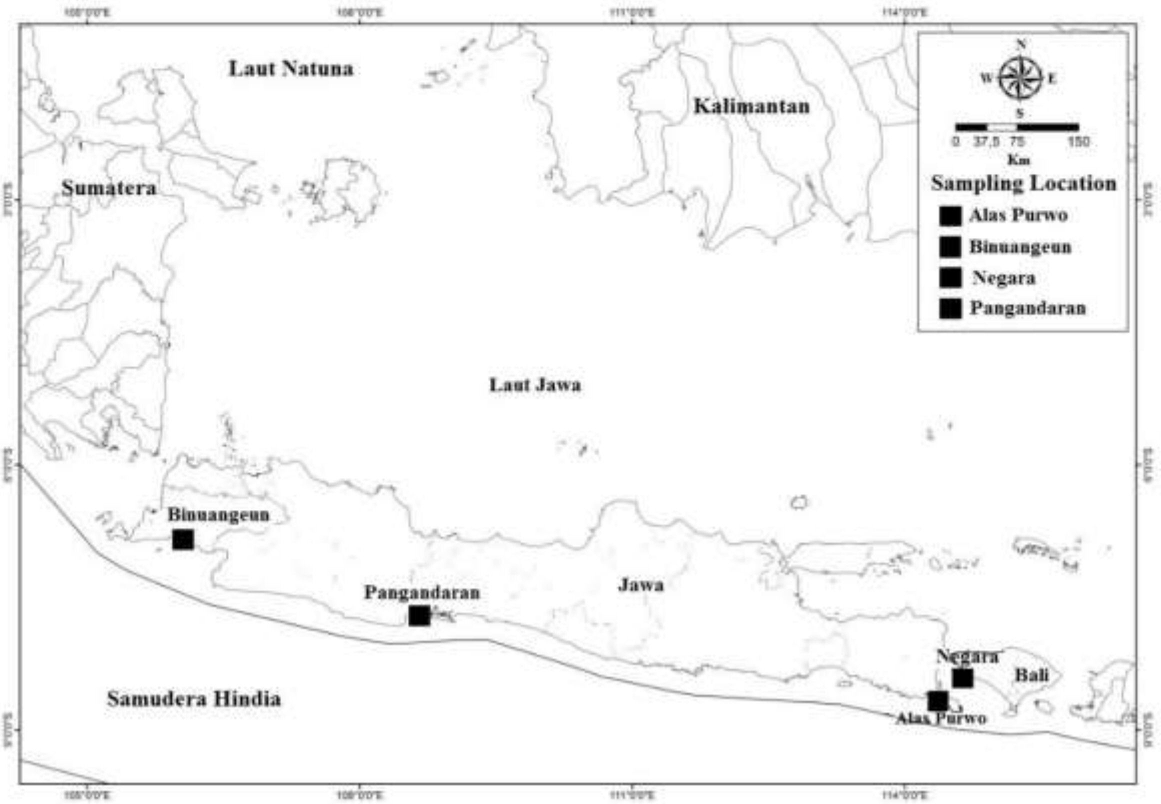


Figure 1. Map of sampling locations in Southern Coastal Java and Bali.

2.3. Morphometric Truss Measurement

Measurements of morphometric characters include signs made on the shell (Figure 2a). Determination of the point in connecting the lines on the shell starting from the growing point (apex). Character (1) FD=SL is the length of the shell formed from the posterior endpoint by passing the apex to the last open hole. Character (2) AC is a line formed from the point of the suture end through the apex and the last closed hole to the point of the left side of the upper shell. Character (3) CE is the width of the shell, the line formed from the line point (CA) on the upper left side by passing through the shell length line (FD) to the right side point of the lower shell. Character (4) AH is a line formed from the point of the line (AC) on the suture through the intersection between the length of the shell (FD) and the width of the shell (CE) to the anterior. Character (5) AF is a line formed from the point of the line (AH) on the suture to posterior. Character (6) AD is a line formed from the point of the line

(AF) on the suture to the last open hole. Character (7) AE is a line formed from a point (AD) on the suture to the lower right side. Character (8) CH is a line formed from a line point (CA) on the upper left side to anterior. Character (9) CD is a line formed from a line point (CH) on the upper left side to the last open hole. Character (10) DB is a line formed from a line point (DC) in the last open hole through the last closed hole to the posterior left side. Character (11) BF is a line formed from a line point (BD) on the left side posterior to the posterior. Character (12) BA is a line formed from a line point (BF) on the left side of the posterior to the point of the suture. Character (13) BG is a line formed from a line point (BA) on the posterior left side through a line of intersection between shell length (FD) and shell width (CE) to anterior margin point. Character (14) GE is a line formed from the point of the line (GB) in the anterior margin to the point of the lower right side. Character (15) GD is a line formed from the line point (GE) on the anterior margin to the last open hole. Character (16) BC is a line formed from a line point (BG) on the left side of the posterior to the upper left side point. Then each measurement point is connected and measured using a caliper (accuracy level 0.01 mm). The measured character consists of 16 characters (Figure 2b, Table 2). Morphometric characters in each abalone individual are divided by the standard length (SL) and are expressed as data on morphometric ratios.

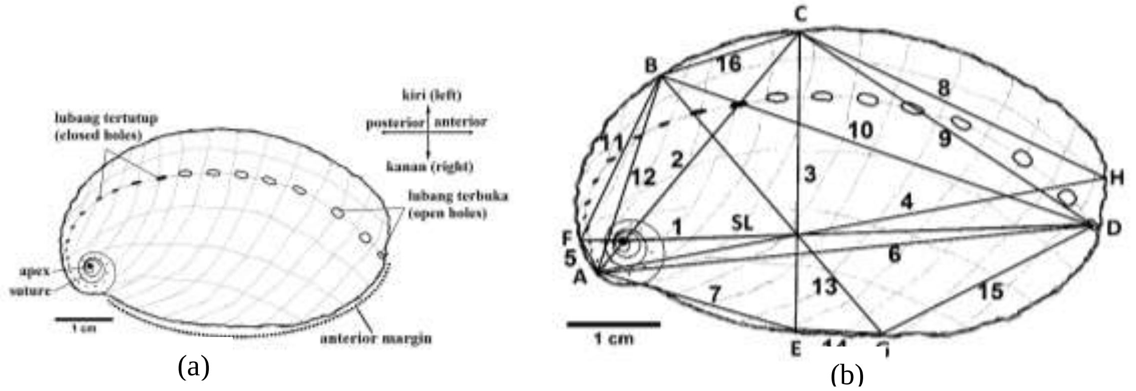


Figure 2. (a) Shell morphology, (b) Design of *Haliotis quamata* shell morphometric truss.

Table 2. Character information measured on *H. squamata* shells.

Character Code	Description of Line and Distance of Measurement Point
FD	Posterior point by passing apex – last open hole (shell length)
AC	The suture point passes through the apex and the last closed hole – point the left side of the upper shell
CE	Line point (CA) on the upper left side by passing the shell length line (FD) – point of the right side of the lower shell (shell width)
AH	Point of the line (AC) on suture through the intersection of shell length (FD) and shell width (CE) – anterior
AF	Line point (AH) on the suture – posterior
AD	Line point (AF) on the suture – last hole
AE	Line point (AD) on the suture – bottom right side
CH	Line point (CA) on the upper left side – anterior

Character Code	Description of Line and Distance of Measurement Point
CD	Line point (CH) on the upper left side – the last open hole
DB	Line point (DC) in the last open hole through the last closed hole – posterior left side
BF	Line point (BD) on the left side of the posterior – posterior
BA	Line point (BF) on the left side of the posterior – suture
BG	Line point (BA) on the posterior left side through a line of intersection between shell length (FD) and shell width (CE) – anterior margin
GE	Line point (GB) in the anterior margin – bottom right side
DG	Line point (GE) in the anterior margin – the last open hole
CB	Line point (BG) on the left side of the posterior – upper left side

2.4. Data Analysis

Morphometric ratio data were analyzed by the Principal Component Analysis (PCA) method which aims to separate the population based on strong characters/differentiating keys on the intraspecies, analysis using Minitab 16 software. Canonical discriminant analysis was conducted to determine the percentage value of sharing components between locations analyzed using SPSS 16. Cluster analysis using linkate method average was conducted to determine the similarity index between populations compared to using Minitab 16 software. PC combination is done to get the best PC combination results. Characters with an absolute value of a factor of 0.3% are combined to find the best character (Gustiano *et al.*, 2004). The best PC combination will be carried out scatter plots to obtain character combinations that separate the *H. squamata* species from four locations.

III. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Analysis Based on PCA

The identification of abalone morphology found in several provinces in the waters of South Java and Bali are species of *H. squamata*. Result data on measurements of morphometric characters (Table 3), after being analyzed by PCA showed that the combination of PCIII and PCIV is a combination that can separate *H. squmata* populations from waters southern of Java and Bali (Figure 3; Table 4).

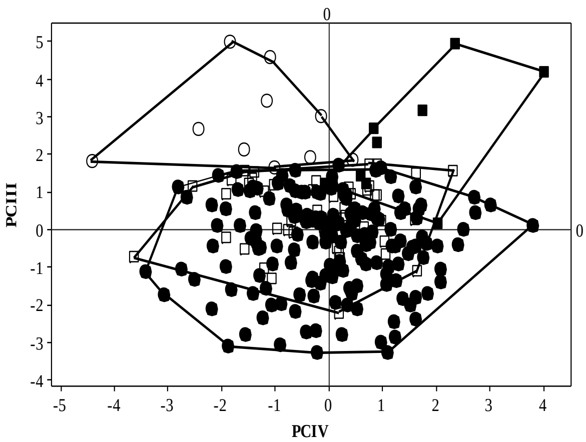


Figure 3. Grouping of intrapopulation *H. squamata*. Combination of PCIII and PCIV.
● Banten, □ West Java, ■ East Java, o Bali.

The results of the PC analysis show that the factor coefficient values that separate the population of *H. squamata* Java and Bali in PCIII include characters (11) of BF: line point (BD) on the left side of the posterior – posterior point, characters (12) of BA: line point (BF) on the left side of the posterior – suture point, characters (10) of DB: line point (DC) in the last open hole through the last closed hole – posterior left side, and characters (16) of CB: line point (BG) on the left side of the posterior – upper left side point. For PCIV is characters (8) of CH: line point (CA) on the upper left side – anterior point, characters (2) of AC: the suture point passes through the apex and the last closed hole – point the left side of the upper shell, characters (14) of GE: line point (GB) in the anterior margin – bottom right side point, characters (6) of AD: line point (AF) on the suture – last hole point, characters (5) of AF: line point (AH) on the suture – posterior point, characters (9) of CD: line point (CH) on the upper left side – the last open hole, and characters (1) of FD: posterior point by passing apex – last open hole (shell length) (Table 4).

The best combination of characters that separates *H. squamata* from Java and Bali include characters (11) of BF: line point (BD) on the left side of the posterior – posterior point and characters (8) of CH: line point (CA) on the upper left side – anterior point (Figure 4). But the results of the combination of characters performed still show overlap on the scatter plot, this is presumably because the population is still in the process of changing for different.

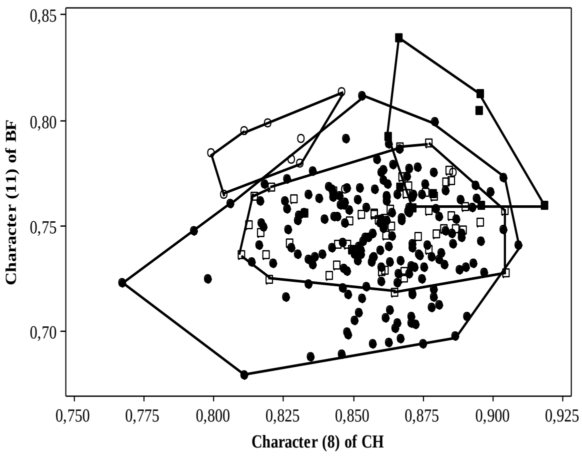


Figure 4. The combination: characters (11) of BF: line point (BD) on the left side of the posterior – posterior point and characters (8) of CH: line point (CA) on the upper left side – anterior point.
● Banten, □ West Java, ■ East Java, o Bali.

Table 3. Measurement of intrapopulation *H. squamata* morphometric characters after divided by the standard length (SL).

Populations		Character code															
		FD	AC	CE	AH	AF	AD	AE	CH	CD	DB	BF	BA	BG	GE	DG	CB
Banten	Max	1.05	0.95	0.98	1.03	0.64	1.03	0.84	0.91	0.95	1.14	0.81	0.89	0.99	0.71	0.80	0.85
	Min	1.01	0.87	0.80	0.99	0.52	0.92	0.70	0.77	0.77	0.88	0.68	0.75	0.91	0.58	0.68	0.64
	Average	1.02	0.92	0.90	1.01	0.58	1.00	0.78	0.86	0.91	0.98	0.74	0.81	0.95	0.64	0.75	0.76
	SD	0.01	0.01	0.02	0.01	0.02	0.01	0.03	0.02	0.02	0.04	0.02	0.02	0.01	0.03	0.03	0.04
West Java	Max	1.07	0.95	0.93	1.04	0.63	1.08	0.82	0.90	0.95	1.09	0.79	0.87	0.98	0.68	0.81	0.83
	Min	1.01	0.90	0.89	1.00	0.53	0.99	0.75	0.81	0.87	0.90	0.72	0.79	0.93	0.57	0.73	0.71
	Average	1.02	0.92	0.91	1.01	0.57	1.00	0.79	0.86	0.91	0.97	0.75	0.82	0.95	0.62	0.77	0.76
	SD	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.03	0.02	0.01	0.01	0.02	0.02	0.02
East Java	Max	1.03	0.94	0.94	1.03	0.63	1.01	0.86	0.92	0.93	1.01	0.84	0.92	0.98	0.70	0.85	0.74
	Min	1.01	0.82	0.90	1.00	0.51	0.99	0.77	0.86	0.90	0.84	0.76	0.82	0.93	0.61	0.69	0.66
	Average	1.02	0.91	0.91	1.01	0.57	1.00	0.81	0.88	0.91	0.93	0.78	0.85	0.96	0.65	0.75	0.71
	SD	0.01	0.04	0.01	0.01	0.04	0.00	0.03	0.02	0.01	0.05	0.03	0.03	0.01	0.03	0.05	0.03
Bali	Max	1.04	0.97	0.93	1.03	0.62	1.04	0.79	0.89	0.93	1.02	0.81	0.90	0.97	0.65	0.80	0.77
	Min	1.02	0.91	0.88	1.00	0.52	1.00	0.73	0.80	0.87	0.86	0.76	0.82	0.92	0.62	0.73	0.64
	Average	1.02	0.93	0.91	1.01	0.57	1.01	0.77	0.83	0.90	0.93	0.78	0.85	0.94	0.63	0.77	0.71
	SD	0.01	0.02	0.01	0.01	0.03	0.01	0.02	0.03	0.02	0.05	0.01	0.03	0.02	0.01	0.02	0.04

Table 4. Coefficient factor values of PCIII and PCIV from intrapopulation of *H. Squamata*.

Number	Character Code Number	Character Code	PCIII	PCIV
1	1	FD	-0.103	-0.270
2	2	AC	0.007	-0.380
3	5	AF	-0.101	0.306
4	6	AD	-0.048	-0.349
5	8	CH	-0.074	**0.522**
6	9	CD	-0.049	0.280
7	10	DB	-0.475	-0.088
8	11	BF	**0.535**	-0.042
9	12	BA	0.518	-0.029
10	14	GE	-0.088	0.363
11	16	CB	-0.348	-0.135

3.1.2. Component Sharing Value

The percentage of the sharing component in the population of *H. squamata* show that the population from Bali has the highest value is 100%, compared to the population of West Java 84.9%, Banten 77.2%, and East Java 55.6% (Table 5). the percentage sharing component value that lowest of between population is 0% for the Bali population with other populations.

Table 5. The percentage value of sharing components intrapopulation based on canonical discriminant.

Populations	Banten (%)	West Java (%)	East Java (%)	Bali (%)	Total (%)
Banten	77.2*	16.4	2.3	4.1	100
West Java	11.3	84.9*	3.8	0	100
East Java	11.1	11.1	55.6*	22.2	100
Bali	0	0	0	100*	100

* percentage value of sharing components Intrapopulation.

3.1.3. Cluster Analysis

The morphometric characters of the four population of *H. squamata* showed a large similarity between the population of Binuangeun and Pangandaran, compared to the population of East Java and Bali which have a small similarity. The intrapopulation relationship based on the morphometric similarity of the population Banten and West Java reached 99.91%, while the East Java and Bali populations of 99.31% (Figure. 5).

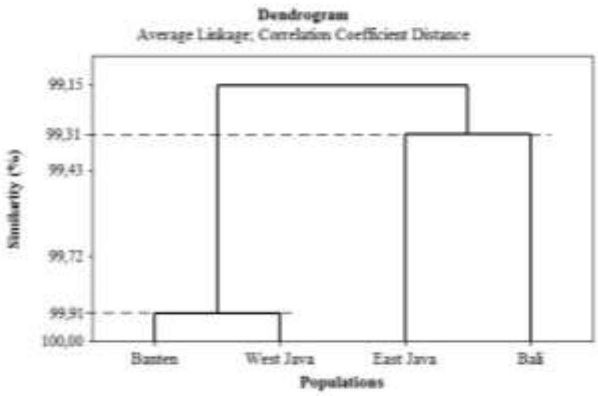
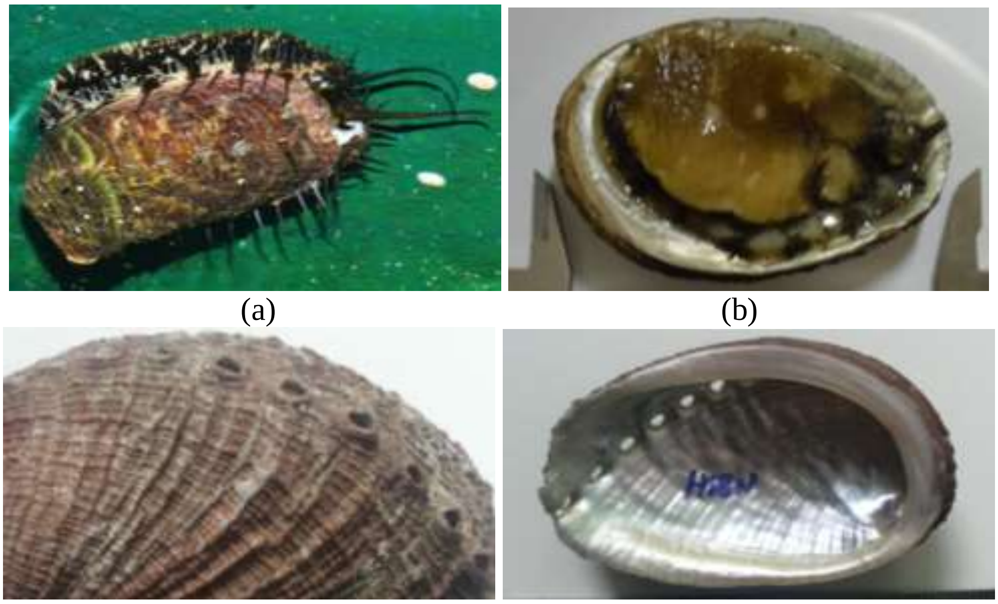


Figure 5. Dendrogram similarity of intrapopulation of *H. Squamata*.

3.1.4. Morphological Description

The morphological characteristics of *H. squamata* found in this study show body characteristics, epipodium and black tentacles with white spots (Figure 6a), then the portion of the leg muscle is yellow with the shell covered (Figure 6b). The characteristics of *H. squamata* shell are oval with a thick texture, rough and wavy outer surface (Figure 6c). The surface of the inner wall is coated by nacre (Figure 6d). The outer surface of the shell is greenish-brown in color with a round and slightly protruding hole structure. The number of open shell holes is eight. The morphology of the shell observed in the abalone population included the thickness of the shell, color, and style (Table 6).



(a) (b) (c) (d)

Figure 6. (a) Abalone of *H. squamata*, (b) the portion of the leg muscles covered in the shell, (c) outer shell surface and (d) the inside of the shell.

Table 6. Shell morphology of Abalone *H. squamata* from four locations.

No.	Province	Location	Shell image	Description
1.	Banten	Binuanguen		reddish color with white patches and thick texture

No.	Province	Location	Shell image	Description
2.	West Java	Pangandaran		reddish color with white patches and thick texture
3.	East Java	Alas Purwo		brown with a thin texture and a greenish-colored groove pattern
4.	Bali	Negara		brownish color with white patches and with a medium thick texture

3.2. Discussion

A total of 260 individuals were analyzed from four locations (Banten, West Java, East Java, and Bali). The results from 16 characters measured show that combined of PCIII and PCIV can separate the Java and Bali populations. Characters that show a factor value of 0.3-0.5 are characters suspected of having a role in the separation of the population Java and Bali. There are four characters from the PCIII component and seven characters from the PCIV component. The combination of characters BF (0.535) for PCIII and characters CH (0.522) for PCIV are key characters that describe the separation of Java and Bali populations. Gustiano *et al.* (2004) reported that the coefficient value of the results of PCA analysis in the genus of *pangasius* showed a group separation between these species. McShane *et al*. (1994) reported that variations in the length shells of *H. iris* were influenced by habitats that were unprotected and protected by waves. Yokoyama and Amaral (2010) also reported that morphometric variations between populations could be influenced by several factors such as differences in shell size and age differences. The availability of food resources and environmental parameters play an important role in the growth rate of gastropods (Yokoyama and Amaral, 2010). Burhanis *et al*. (2018) reported that the topography of the waters had an effect on the distribution of the size of the type of yellowfin tuna in the waters of Simeulue. Factors of environmental conditions and genetic greatly influence changes in the morphological characteristics of both populations from Java and Bali. In Indonesia, famous for two currents: seasonally-reversing current and Cross-Indonesian Flow (Wyrtki, 1961). Both currents are thought to have an important role in the spread of *H. squamata* abalone in Indonesian waters. Miyake *et al*. (2011) reported that the distribution of abalone planktonic larvae depends on the abalone period, which is divided into two types, namely the flow type and the settling type near the spawning area. Thus, the morphological characters that separate the two populations are thought to be characters that experience adaptation to the environment.

The highest share component in the population is 100% for the Bali population, while among the lowest intrapopulation is 0% for Bali population and other populations.The value of the uniformity of the shell size of Bali population shows no measurable mixing with the Java population. This high uniformity in the Bali population is suspected because the Bali population was geographically separated from the Java population. Soewardi (2006) revealed that the value of similarity in body size provides an explanation of measured mixing between populations one with another population. Radona *et al.* (2016) reported that in Java tengadak fish populations male and female *Barbonymus schwanenfeldii* had a uniformity index higher than Kalimantan and Sumatra based on canonical discriminant. Morphological characters can be influenced by the adaptation and selection of a population to changes in environmental conditions (Soewardi, 2007). Thus the high phenotypic character diversity in the Bali population is thought to be due to an interaction between environmental. Wang *et al*. (2004) revealed that environmental conditions, genetic factors, and genetic and environmental interactions can influence differences in phenotypes. The high similarity of the population of Binuangeun and Pangandaran is suspected because the two populations still have similar environmental conditions, so the carrying capacity for the development of the two populations tends to be uniform. In contrast, the Alas purwo and Bali populations show the lowest similarity.

Characteristics of shell in the abalone morphology of the population Banten and West Java have thick characteristics, of the population East Java with thin shell thick and the Bali population with medium shell thick, this character is specific to each location. The there of distinctive characteristics of the shell morphology are thought to be due to environmental factors such as availability of feed, water temperature, and habitat conditions (McShane *et al*., 1988; Wang *et al*., 2004). Liu *et al*. (2009) found the effect of macroalgae on variations in the shell color pattern of abalone *H. discus hannai*.

The morphometric truss research on the topic of *H. squamata* from various locations is one of the breakthroughs and innovations that have never been carried out systematically. Identification using the morphometric truss method in this study has found the character (distinguishing) or differentiating intrapopulation of abalone *H. squamata*. Thus these distinguishing characters can be used as a basis in identifying abalone species.

IV. CONCLUSION

The characters that separate the Java and Bali population groups are four characters from the PCIII component and seven characters from the PCIV component. High uniformity in the population was found in the Bali population, whereas intrapopulation showed low uniformity in the Bali population with other populations. The highest percentage of similarity between populations was the population of *H. squamata* from Banten and the population of *H. squamata* from West Java followed by the East Java population and Bali population. The morphological characteristics of *H. squamata* species at several locations showed specific characteristics of the shell thickness.

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