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[biosaintifika] Colour and Morphometric Variation of Donacid Bivalves from Nepa Beach, Northern Shores of Madura Island, Indonesia

1 message

Dr. Ir. Dyah Rini Indriyanti <dyahrini36@gmail.com> Thu, Sep 28, 2017 at 8:02 AM
Reply-To: "Dr. Ir. Dyah Rini Indriyanti" <biosaintifika@gmail.com>
To: Reni Ambarwati <reniambarwati@unesa.ac.id>, Ulfi Faizah <ulfifaizah@unesa.ac.id>

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Terima kasih atas review yang telah diberikan. Bersama ini saya kirimkan naskah yang telah kami perbaiki sesuai masukan. Selain itu, juga telah kami sitasi 2 artikel Biosantifika.
Mohon informasi untuk tahap selanjutnya.

Terima kasih

Salam

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Biosaintifika Unnes <biosaintifika@gmail.com> Tue, Oct 3, 2017 at 7:56 PM
To: "Reni Ambarwati ." <reniambarwati@unesa.ac.id>

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Reni Ambarwati . <reniambarwati@unesa.ac.id> Thu, Oct 5, 2017 at 2:55 PM
To: Biosaintifika Unnes <biosaintifika@gmail.com>, Dyah RiniIndriyanti <dyahrini36@gmail.com>

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Terima kasih atas emailnya. Berikut ini manuskrip kami yang telah kami sesuaikan sesuai masukan tim editor, yaitu dengan menggunakan reference manager Mendeley dan telah kami cek memenuhi evaluation guidelines yang diberikan (file-file terlampir).
Mohon informasi untuk tahap selanjutnya.

Terima kasih

Salam

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No	Manuscript parts	Description	Answer
1	Manuscript	Total words should be 3500 – 5000 words or the pages should not exceed than 15 pages including figures, tables and bibliographical references, 1.5 line spacing, Times New Roman 12, numbered pages and lines, in MS-Word, or compatible.	Yes, 3971 words
2	Title	The title consists of 12 up to 15 words, must be to the point.	Yes, 13 words
3	Name of authors	The full name(s) of the author(s) (at least 2 authors/ not a single author)	Yes
4	Affiliation	All of the authors' institutional address(es) and the e-mails of the author for correspondence should be inserted	Yes
5	Abstract	Abstracts 150-250 words, contain brief information on:	Yes
		• The Background	Yes
		• Aims/objectives of the research	Yes
		• Methods employed	Yes
		• Results and conclusion	Yes
		• New findings/significance of contribution	Yes
		• Benefit for science development/society	Yes
6	Key words	Key words, 3-5 words or phrases, it represents the article content and should include words found in research database.	Yes
7	Introduction (± 1 page, 1.5 line spacing)	Introduction Include:	Yes
		• The important issues in general and specifically encountered	Yes
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9	Results and Discussion	Results and discussion are combined in one part. It contains:	Yes
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		• Discussion must reveal the in depth analysis of the obtained results it is critically and in-depth synthesis accompanied by proof of evidence related latest references	Yes
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		• Answering the research objectives	Yes
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Colour and Morphometric Variation of Donacid Bivalves from Nepa Beach, Northern Shores of Madura Island, Indonesia

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ABSTRACT

Donacid bivalves vary in colour, pattern, and the shape of the shells. Recently, a population of donacid bivalves is found in the northern shore of Madura Island, Indonesia. This study aimed to identify the donacid found in northern shore of Madura Island as well as to describe their variation on morphometric and morphological characters. Colour and pattern of 215 shells were observed and carefully photographed. Morphometric of the shells including the shell height, shell length, shell width, dorsal length, and umbo-margin length were measured and then their patterns were analyzed using regression analysis. The result revealed that there were two species of donacid bivalves, namely *Donax cuneata* and *Donax faba* with different morphological characteristics, including 12 different patterns and colours of the shells. This study contributes to the research on bivalve taxonomy, and is useful for donacid bivalves identification based on morphological characteristics.
Key words: Donacidae, donacid bivalves, morphological characteristics

INTRODUCTION

Donacids bivalves (Bivalvia: Donacidae) are widely distributed in sandy bottom ecosystems throughout the world. *Donax truncus* can be found in the Mediterranean Sea (Valle *et al.,* 2011) and in sandy beaches in Portugal (Pereira *et al*., 2012). Other members, namely *Donax semistriatus*, *D. vittatus,* and *D. variegatus* have been found in Portugal (Pereira *et al.,* 2012). Herrmann *et al.* (2009) reported the occurrence of *Donax hanleyanus* in sandy beaches of Argentina.

In Western Pacific areas, other donacid bivalves are identified. Lamprell & Whitehead (1998) identified seven species that belong to Donacidae from Australia, such as *Donax deltoides, D. faba, D. cuneata,* and *Donax brazieri*. Previously, Purchon (1981) reported three donacid bivalves from West Malaysia and Singaporean waters, namely *D. cuneata, D. faba*, and *D. incarnatus*, and after almost two decades Tan & Woo (2010) confirmed the occurrence of *D. cuneata* and *D. faba* in Singaporean waters. Hylleberg & Kilburn (2003) reported some donacid bivalves from Vietnam, namely *D. brazieri, D. cuneata, D. dysoni, D. faba, D.*

incarnatus, D. kwsinensis, D. nitidus, D. saigonensis, D. semigranosus, and *D. tinctus*. Thanch (2005) confirmed the occurrence of *D. cuneata dan D. faba* in Vietnam and stated that they were common in this region. The occurrence of *D. cuneata* and *D. faba* was also reported from another areas in Western Pacific, for instance Thailand (Robba *et al.,* 2007; Sanpanich, 2011) and Philippines (Willan, 2011). In addition, *D. faba* was listed as commercial and edible molluscs of Thailand (Nateewathana, 1995; Poutiers, 1998); Indonesia (Poutiers, 1998; Dharma, 2005) as well as Malaysia, Indo-Cina, and the Philippines (Poutiers, 1998).

In Indonesia, there were four species of Donacidae reported by several authors. Based on Siboga expedition, Prashad (1932) identified *Donax (Latona) cuneata* dan *Donax (Latona) faba*. Meanwhile, Roberts *et al.* (1982) noted the occurrence of *D. cuneata* at shallow water of North-West Java. More donacid bivalves reported by Dharma (2005) were as folows: *D. faba* (from Panimbang, West Java), *D. deltoids* (from Central Java, Indian Ocean), and *Hecuba scortum* (from Seribu Islands, West Java). Besides, Dharma (2005) also showed five variation of *D. faba* from West Java.

Donacid bivalves not only have high diversity based on the number of species, but also high variation in morphological aspects including shape variation and colour pattern. Soares *et al.* (1998) noted that two geographically different populations of *Donax serra* showed shapes and colour variations and argued that those morphological plasticities related to their habitat condition. Tan & Low (2013) described that Singaporean *Donax cuneata* has white, cream, brown, and grey coloration, and also radial bands pattern. In addition, Tan & Low (2013) also described that *Donax faba* found in Singapore varies in shell shape, and coloration pattern. These findings highlighted the possibility that wide range of distinctive morphological characters of donacid bivalves can be related to their habitat.

Recently, a dense population of donacid bivalves has been found in sandy beach located on the northern shore of Madura Island. Madura Island is a relatively big island in East Java, Indonesia, located in Western Pacific area. The occurrence of donacid bivalves in Madura Island has thus far not been reported. This paper describes these donacid bivalves and examines their morphological variation.

Please explain The benefits of the research to the science / society (2-3 lines)

MATERIALS AND METHODS

Sampling and Preservation

Samples were collected from Nepa Beach, Sampang, Madura, Indonesia. Living bivalves were relaxed by using $MgCl_2.6H_2O$ 7.3% in sea water, and then preserved in Ethanol 70%. Shells were cleaned in fresh water before drying for storage. Exterior and interior of 215 shells was observed carefully under a magnifying lamp.

Identification and Measurement

Specimens were identified based on morphological characters of the shells. Morphometric measurements of the specimens were taken by calipers 0.05 mm. Shell length (SL) was defined as the perpendicular distance between the anterior and posterior ends of the shells. Shell height (SH) was measured from the highest part of the dorsal side to the lowest part of the ventral side of the shells. Shell width (SW) was defined as the distance between the most prominence parts of the lateral side of the two shells. Dorsal height (DH) was measured from the highest part of the dorsal side to an imaginary line that was perpendicular between the anterior and posterior ends of the shells. Umbo margin line (UML) was defined as the distance from the highest part of the dorsal side of the shell to the posterior end of the shell. Abbreviations used for collections are: MZB.PEL= bivalves collection of Museum Zoologicum Bogoriense (Research Center for Biology – Indonesian Institute of Science); and RA = collection of author.

Data Analysis

The other morphological characters of the shell such as colour, band pattern, and the shape of the shell, were descriptively analyzed, while the patterns of shell morphometric were analyzed by regression analysis.

RESULTS AND DISCUSSION

Identification placed specimens into two different species of donacid bivalves found in Nepa, northern shores of Madura Island Indonesia, namely *Donax cuneata* and *Donax faba*. Systematic accounts of these two species were described as follows.

Donax (*Latona*) *cuneata,* Linnaeus 1758

Donax cuneata Linnaeus, 1758: 683; Prashad, 1932: 202; Lamprell & Whitehead, 1992: plate 51, 379; Hylleberg & Kilburn, 2002: page 67 (list); Hylleberg & Kilburn, 2003: page 207 (list); Dharma, 2005: Plate 108, Page 267; Huber, 2010.

Materials examined: 91 specimens including RA133 and MZB.PEL.2100, Indonesia, Madura, northern shore, Nepa, S6º53.673’ E113º06.673’, Coll. Reni Ambarwati, 15 May 2014.

Shell: thick, compressed, distinctly inequilateral, trigonal-ovate in outline. Shell length to up 31.75 mm; shell height up to 28.1 mm; shell width up to 19.9 mm. Sculpture: smooth with fine concentric lines, radial sculpture distinct at posterior end, forming reticulate scale-like sculpture. Umbo: inflated, prosogyrate. Colour: white, cream, brown, grey; usually with radial bands of varying thickness and prominence; interior white to purple, often with tinted yellow, brown or purple blotch. Dentition: heterodont with anterior and posterior lateral teeth. Interior of the shell: elongated anterior adductor scar and rounded posterior adductor scar; deep palial sinus (approximately ½ of shell length); obvious palial line (Figures 1-2).

Habitat: these bivalves were buried shallowly in the sand of intertidal zone.

Donax (*Latona*) *faba* Gmelin, 1791

Donax faba Gmelin, 1791: 3264; Prashad, 1932: 203; Lamprell & Whitehead, 1992: plate 51, 379; Hylleberg & Kilburn, 2002: page 67 (list); *Donax faba* Gmelin, 1971 Hylleberg & Kilburn, 2003: page 207 (list); Dharma, 2005: Plate 108, Page 380; Huber, 2010.

Materials examined: 124 specimens including RA107 and MZB.PEL.2101, Indonesia, Madura, northern shore, Nepa, S6º53.673' E113º06.673', Coll. Reni Ambarwati, 15 May 2014.

Shell: thick, compressed, inequilateral, triagonal-ovate in outline. Shell length up to 26.8 mm; shell height up to 19.9 mm; shell width up to 18.4 mm. Sculpture: surface smooth with fine concentric lines that are usually more pronounced and appear as ridges on the posterior side. Umbo: inflated, prosogyrate. Colour: white, cream, brown, purple; often with one or more radial bands and random wide spots; interior white, often with shaded yellow or with purplish blotches, to purple, usually with whitish blotches and/or radial bands. Dentition: heterodont with anterior and posterior lateral teeth. Interior of the shell: elongated anterior adductor scar and rounded posterior adductor scar; deep palial sinus (approximately ½ of shell length); obvious palial line (Figures 3-4).

Habitat: these bivalves were buried shallowly in the sand of intertidal zone.

Donax cuneata and *Donax faba* can be distinguished on the basis of their morphological characteristics. *Donax cuneata* have radial ridges at the posterior end of the shell which can be seen as reticulate scale-like sculpture, while *D. faba* lack of these sculpture, but they have fine concentric lines at the posterior and ventral part of the shell. Furthermore, these two bivalves can be differentiated based on their morphometric patterns.

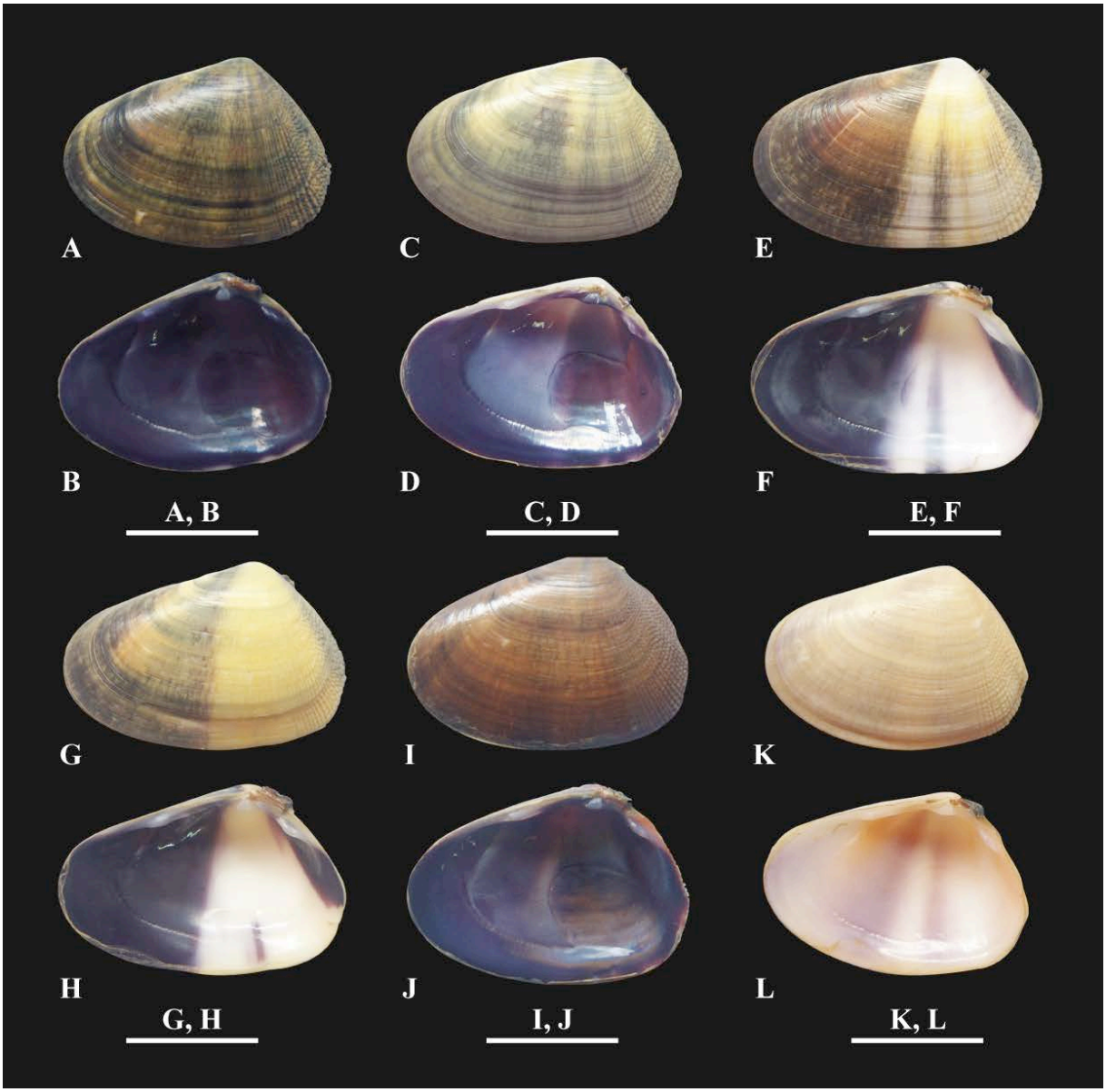

Figure 1. Variation in *Donax cuneata* collected from Madura Island; A,B: Type 1; C,D: Type 2; E,F: Type 3; G,H: Type 4; I,J: Type 5, K,L: Type 6; scale bar: 10 mm.

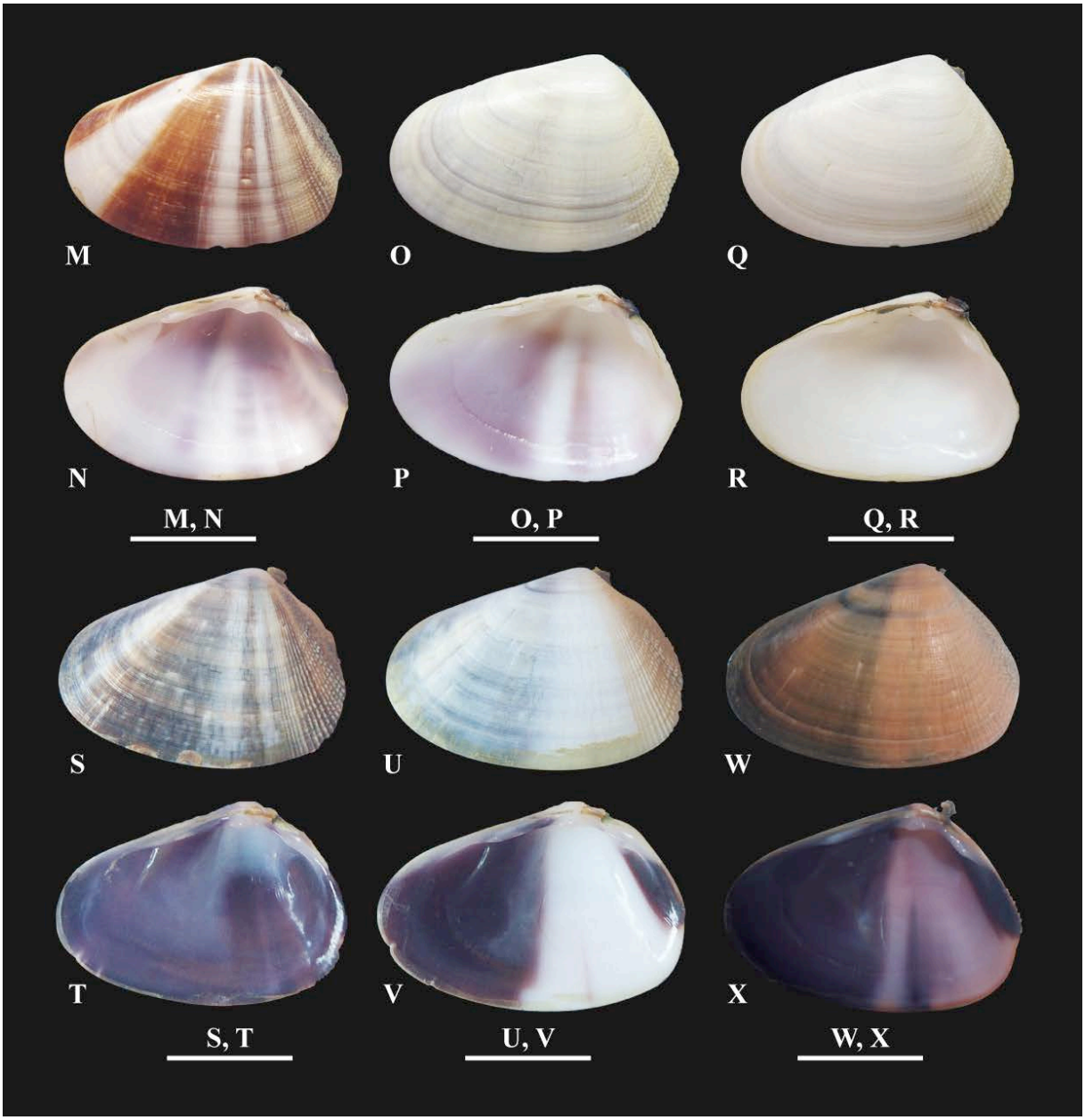

Figure 2. Variation in *Donax cuneata* collected from Madura Island; M,N: Type 7; O,P: Type 8; Q,R: Type 9; S,T: Type 10; U,V: Type 11, W,X: Type 12; scale bar: 10 mm.

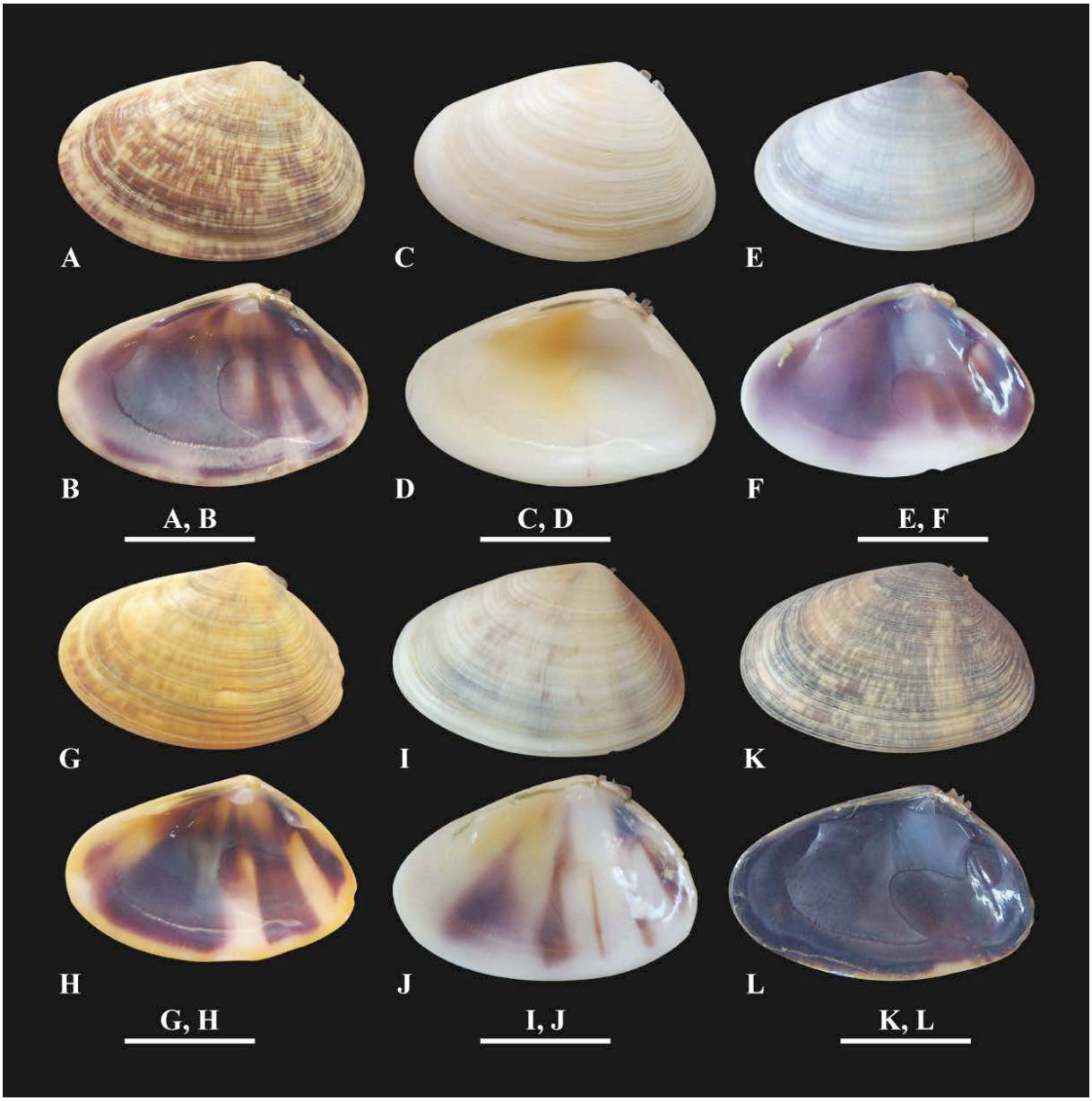

Figure 3. Variation in *Donax faba* collected from Madura Island; A,B: Type 1; C,D: Type 2; E,F: Type 3; G,H: Type 4; I,J: Type 5, K,L: Type 6; scale bar: 10 mm.

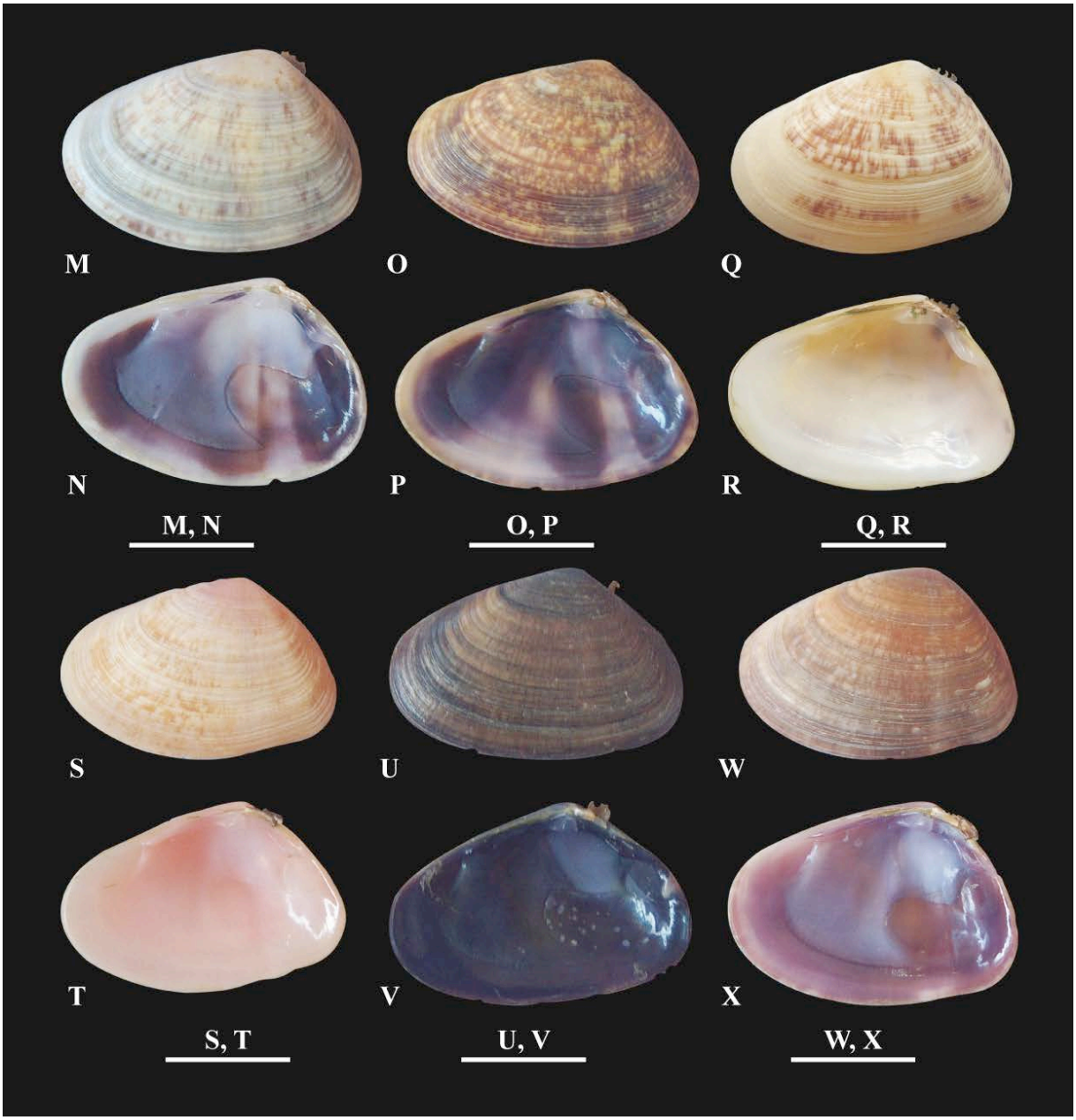

Figure 4. Variation in *Donax faba* collected from Madura Island; M,N: Type 7; O,P: Type 8; Q,R: Type 9; S,T: Type 10; U,V: Type 11, W,X: Type 12; scale bar: 10 mm.

Donax cuneata collected from Madura Island were bigger than *D. faba*. The length of *Donax cuneata* could reach 31.75 mm, while the length of *Donax faba* was up to 26.8 mm. Moreover, the anterior part of the former was more likely to become wider than the latter. In addition, most of *Donax cuneata* shells were thick, and this could be observed in the width of the shells. The shell width of *Donax cuneata* could reach 19.9 mm and the ratio of shell width and shell height (SW/SH) was 0.5, while shell width of *Donax faba* was up to 18.4 mm and the ratio of shell width and shell height (SW/SH) was 0.48 (Table 1). The relationship of shell height and shell length of *D. cuneata* can be shown by regression equation SH= -1.234+0.772SL, whereas equation for *D. faba* was SH= -4.795+ 0,4795SL. Moreover, the relationship of shell shell width and shell length of *D. cuneata* can be shown by regression equation SW= -2.924+0.482SL, whereas equation for *D. faba* was SW= -0.716+ 0,374SL (Table 1). However, the size and colour of sampled shells collected from Madura Island was highly varied.

Table 1. Comparison of morphometric features of *Donax cuneata* and *Donax faba*

	Donax cuneata	***Donax faba***
Shell length (SL) (mm)	24.52±4.22 (13.5-31.75)	21.27±3.02 (6.6-26.8)
Dorsal height (DH) (mm)	14.80±3.40 (6.8-21.9)	12.06±1.65 (7.2-15.8)
Shell height (SH) (mm)	17.70±3.51 (8.3-24.8)	14.99±1.84 (9.2-19.9)
Distance of Umbo-Anterior Margin (mm)	17.75±3.62 (7.8-25.5)	15.03±2.23 (9.2-20.9)
Shell width (mm)	8.90±2.45 (3.9-19.9)	7.24±2.10 (3.1-18.4)
SW/SL ratio	0.36	0.34
SW/SH ratio	0.50	0.48
SH/SL ratio	0.72	0.71
Relationship SW ×SL	SW= -2.924+0.482SL	SW= -0.716+0.374SL
Relationship SW ×SH	SW= -1.420+0.583SH	SW= -1.797+0.603SH
Relationship SH ×SL	SH= -1.234+0.772SL	SH= -4.795+0.479SL

Note: SW: shell width, SL: shell length, SH: shell height

Both of *Donax cuneata* and *Donax faba* varied among the individual in population, including colour, shape, and size. There were 12 types of colour pattern of *Donax cuneata*. White colour on both exterior and interior was the most frequent pattern in this species and, followed by dark purple with tinted yellow exteriorly and dark purple interiorly (Table 2). Similar with *D. cuneata, D. faba* also were found in 12 types of colour pattern. The pattern of

light brown with brown maculation exteriorly and yellow with purple maculation interiorly was the most frequent pattern that could be found, followed by Type 5 which was white exteriorly with brown maculation and the interior was white tinted purple (Table 3).

Table 2. Colour and morphometric variation of *Donax cuneata*

Type	Shell colour	n	SL (mm)	DH (mm)	SH (mm)	UML (mm)	SW (mm)	Ratio		
								SW/ SL	SW/ SH	SH/ SL
Type 1	ext: dark purple with tinted yellow; int: dark purple	19	24.66±4.14	15.35±4.46	18.27±3.38	18.30±3.39	9.14±2.18	0.37	0.50	0.74
Type 2	ext: yellowish purple; int: dark purple	15	23.67±4.54	14.20±3.13	16.76±4.35	16.83±4.34	8.58±3.79	0.35	0.51	0.70
Type 3	ext: half anterior brown, half posterior white with white band; int: half anterior purple, half posterior white with purple band	8	26.40±3.34	15.54±1.82	19.01±2.22	19.13±4.09	9.16±1.56	0.35	0.48	0.72
Type 4	ext: half anterior brown, half posterior yellow with purple band; int: half anterior purple, half posterior white with purple band	1	30.8	19.5	20.9	21.9	11.3	0.37	0.54	0.68
Type 5	ext: brown; int: purple	10	22.17±1.25	12.60±1.64	15.49±1.65	16.19±1.65	8.36±1.50	0.38	0.54	0.70
Type 6	ext: cream; int: cream with purple blotch	4	25.55±5.20	15.55±3.97	19.05±4.44	19.50±3.79	9.48±2.69	0.37	0.49	0.74
Type 7	ext: white with brown radial bands; int: white with purple blocth	4	21.38±6.87	12.05±3.98	14.88±5.35	16.15±6.89	7.40±2.96	0.34	0.49	0.69
Type 8	ext: yellowish white; interior: white with purple blocth	2	27.55±3.46	15.30±0.28	18.25±1.34	20.63±4.14	9.30±0.99	0.34	0.51	0.66
Type 9	ext: white; interior: white	24	25.36±4.34	15.60±3.32	18.61±3.30	17.79±3.20	9.16±2.52	0.36	0.49	0.73
Type 10	ext: purplish brown with white radial band; int: purple	1	19.6	12.5	14.2	15.3	7.2	0.37	0.51	0.72
Type 11	ext: white; int: half anterior purple, half posterior white with purple spot	1	21.6	12.9	14.4	15.8	7.4	0.34	0.51	0.67
Type 12	ext: brown with broad purple band anteriorly; int: dark purple with tinted light purple	2	25.50±0.85	15.70±1.56	18.55±1.91	18.40±1.27	9.45±1.20	0.37	0.51	0.73

Note: n: number of examined shell, SL: shell length, SW: shell height, width, DH: dorsal height, SH: shell height, UML: umbo margin line, ext: exterior, int: interior.

Table 3. Colour and morphometric variation of *Donax faba*

Type	Shell colour	n	SL (mm)	DH (mm)	SH (mm)	UML (mm)	SW (mm)	Ratio		
								SW/ SL	SW/ SH	SH/ SL
Type 1	ext: light brown with brown maculation; int: yellow with purple maculation	42	21.41±2.95	11.97±1.60	15.10±1.97	15.09±2.06	7.16±1.57	0.34	0.47	0.71
Type 2	ext: white; int: white tinted yellow	6	17.73±5.88	11.72±2.24	14.30±2.20	13.98±2.48	6.22±1.29	0.40	0.43	0.91
Type 3	ext: purplish white; int: purple with white spot at ventral margin	2	21.85±1.48	12.28±1.17	14.80±0.57	15.60±1.41	6.75±0.92	0.31	0.46	0.68
Type 4	ext: yellow with brown maculation; int: purple with yellow spot	6	24.08±1.65	12.94±1.23	16.49±1.68	17.63±2.38	9.05±2.79	0.38	0.55	0.68
Type 5	ext: white with brown maculation; int: white tinted purple	26	20.69±2.11	11.78±1.62	14.77±1.74	14.41±1.88	6.42±1.00	0.31	0.44	0.71
Type 6	ext: purplish brown; int: dark purple	9	20.82±3.45	11.82±1.24	14.57±1.39	14.48±2.21	6.72±1.44	0.32	0.46	0.71
Type 7	ex: white with brown maculation; int: purple tinted white at ventral margin	2	21.80±0.14	12.35±1.77	15.30±1.27	15.85±0.92	7.65±1.48	0.35	0.50	0.70
Type 8	ext: brown with cream maculation; int: purple tinted white at ventral margin	4	23.15±1.50	12.13±1.20	15.99±0.90	15.78±2.67	7.51±1.01	0.33	0.47	0.69
Type 9	ext: cream with brown maculation; int: cream	20	21.19±2.95	12.21±1.94	14.59±1.91	15.12±2.24	7.94±3.42	0.37	0.53	0.69
Type 10	ext: pinkish cream with brown maculation; int: pinkish cream	3	22.23±3.52	13.07±2.51	15.87±2.36	15.67±2.53	7.72±2.03	0.34	0.48	0.71
Type 11	ext: dark brown; int: dark purple	3	21.85±0.97	11.87±0.31	14.07±0.61	12.97±1.76	9.27±4.53	0.42	0.65	0.64
Type 12	ext: brown; int: light purple	1	25.9	15.8	18.1	20.9	9.1	0.35	0.50	0.70

Note: n: number of examined shell, SL: shell length, SW: shell height, width, DH: dorsal height, SH: shell height, UML: umbo margin line, ext: exterior, int: interior.

Colour and pattern of *Donax cuneata* and *Donax faba* were almost the same, however they had different tendency in pattern. *Donax cuneata* were usually dominant in dark purple and white shell, often found with radial band; while the latter were frequently found in cream shell with random brown maculation formed "batik" pattern. In addition to colour, *Donax cuneata* and *D. faba* could be distinguished on the basis of their sculpture of the shell. *Donax cuneata* had prominence radial ribs at the posterior side, on the other hand *D. faba* only had strong concentric line at this side. This was also confirmed by Tan & Low (2013).

Moreover, the shapes of these two species were different. Although *Donax cuneata* and *Donax faba* were in common shape known as "wedge" (McLachlan *et al.,* 1995) because the average ratio of shell width and shell length were 0.36 and 0.34 respectively, their shapes were not the same. The posterior side of *D. cuneata* was rounded, while posterior side of *D. faba* was often found elongated to the ventral side, such as found in the Type 2, 3, 6, 9, 10, and 12. In addition, *D. cuneata* looked more inequilateral since the umbo margin line was longer (Table 1). The shell *Donax faba* looked more slender than *D. cuneata* because the ratios of shell width and shell length as well as the ratio of shell width and shell height of *D. faba* are smaller than *D. cuneata*. This nature of the shell facilitated their burrowing activities in the sandy beach. Stanley (1970) explained that the wedge-shaped of donacid bivalves was an adaptation for fast burrowing and movement between tide-levels.

There was high variation among the individual of *D. cuneata* collected from Madura Island that could be grouped into 12 types of variation. Previously Tan & Low (2013) had reported this kind of variation among the individuals from Singapore. Among the individual collected from Madura Island, Type 5, which was white exteriorly and interiorly, was the most dominant, followed by Type 1 with dark purple appearance. The morphometric of those types were varied, however, generally they revealed wedge-shaped appearance, namely the ratio of SW/SL ranged 0.34-0.38, the ratio of SW/SH ranged 0.49-0.54, and the ratio of SH/SL was 0.66-0.74.

The similarly high variation was also found among the individual of *D. faba* collected from the same site. Dharma (2005) also recorded five-shell variation of *D. faba* collected from Panimbang, West Jawa, Indonesia. Previous study also reported the variation of *D. faba* in Singapore (Tan & Low, 2013). Among the individual collected from Madura Island, Type 1, which has "batik" appearance (the exterior is light brown with brown maculation) was the

most dominant. The morphometric characters of *D. faba* types were also varied, however, generally they revealed slender wedge-shaped appearance, namely the ratio of SW/SL ranged 0.31-0.4, the ratio of SW/SH ranged 0.43-0.65, and the ratio of SH/SL was 0.64-0.70.

Explain the new finding (penemuan baru) and The benefits and contribution of research for the science/ society (2-3 lines)

CONCLUSION

Donax cuneata and *Donax faba* can be found at Nepa Beach, northern shores of Madura Island, Indonesia. Each of these species has 12 types of shells, based on coloration and morphometric pattern.

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Colour and Morphometric Variation of Donacid Bivalves from Nepa Beach, Madura Island, Indonesia

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ABSTRACT

Donacid bivalves vary in colour, pattern, and the shape of the shells. Recently, a population of donacid bivalves is found in the northern shore of Madura Island, Indonesia. This study aimed to identify the donacid found in northern shore of Madura Island as well as to describe their variation on morphometric and morphological characters. Colour and pattern of 215 shells were observed and carefully photographed. Morphometric of the shells including the shell height, shell length, shell width, dorsal length, and umbo-margin length were measured and then their patterns were analyzed using regression analysis. The result revealed that there were two species of donacid bivalves, namely *Donax cuneata* and *Donax faba* with different morphological characteristics, including 12 different patterns and colours of the shells. This study contributes to the research on bivalve taxonomy, and is useful for donacid bivalves identification based on morphological characteristics.
Key words: Donacidae, donacid bivalves, morphological characteristics

INTRODUCTION

Donacids bivalves (Bivalvia: Donacidae) are widely distributed in sandy bottom ecosystems throughout the world. *Donax truncus* can be found in the Mediterranean Sea (La Valle et al., 2011) and in sandy beaches in Portugal (Pereira et al., 2012). Other members, namely *Donax semistriatus*, *D. vittatus,* and *D. variegatus* have been found in Portugal (Pereira et al., 2012). Herrmann, et al., (2009) reported the occurrence of *Donax hanleyanus* in sandy beaches of Argentina.

In Western Pacific areas, other donacid bivalves are identified. Lamprell & Healy, (1998) identified seven species that belong to Donacidae from Australia, such as *Donax deltoides, D. faba, D. cuneata,* and *Donax brazieri*. Previously, Morris & Purchon (1981) reported three donacid bivalves from West Malaysia and Singaporean waters, namely *D. cuneata, D. faba*, and *D. incarnatus*, and after almost two decades Tan & Woo (2010) confirmed the occurrence of *D. cuneata* and *D. faba* in Singaporean waters. Hylleberg & Kilburn (2003) reported some donacid bivalves from Vietnam, namely *D. brazieri, D.*

cuneata, D. dysoni, D. faba, D. incarnatus, D. kwsinensis, D. nitidus, D. saigonensis, D. semigranosus, and *D. tinctus*. Thach (2005) confirmed the occurrence of *D. cuneata* and *D. faba* in Vietnam and stated that they were common in this region. The occurrence of (Poutiers, 1998)*D. cuneata* and *D. faba* was also reported from another areas in Western Pacific, for instance Thailand (Robba et al., 2006; Sanpanich, 2011) and Philippines (Willan, 2011). In addition, *D. faba* was listed as commercial and edible molluscs of Thailand (Nateewathana, 1995; Poutiers, 1998) ; Indonesia (Poutiers, 1998; Dharma, 2005) as well as Malaysia, Indo-Cina, and the Philippines (Poutiers, 1998).

In Indonesia, there were four species of Donacidae reported by several authors. Based on Siboga expedition, Prashad (1932) identified *Donax (Latona) cuneata* dan *Donax (Latona) faba*. Meanwhile, Roberts et al., (1982) noted the occurrence of *D. cuneata* at shallow water of North-West Java. More donacid bivalves reported by Dharma (2005) were as folows: *D. faba* (from Panimbang, West Java)*, D. deltoids* (from Central Java, Indian Ocean)*,* and *Hecuba scortum* (from Seribu Islands, West Java). Besides, Dharma (2005) also showed five variation of *D. faba* from West Java.

Donacid bivalves not only have high diversity based on the number of species, but also high variation in morphological aspects including shape variation and colour pattern. Soares et al. (1998) noted that two geographically different populations of *Donax serra* showed shapes and colour variations and argued that those morphological plasticities related to their habitat condition. Tan & Low (2013) described that Singaporean *Donax cuneata* has white, cream, brown, and grey coloration, and also radial bands pattern. In addition, Tan & Low (2013) also described that *Donax faba* found in Singapore varies in shell shape, and coloration pattern. These findings highlighted the possibility that wide range of distinctive morphological characters of donacid bivalves can be related to their habitat.

Recently, a dense population of donacid bivalves has been found in sandy beach located on the northern shore of Madura Island. Madura Island is a relatively big island in East Java, Indonesia, located in Western Pacific area. The occurrence of donacid bivalves in Madura Island has thus far not been reported. Previous studies on this island worked on another groups of molluscs. Rahmasari et al. (2015) investigated the diversity and abundance of gastropods in the Southern shores of Madura, meanwhile Rochmawati et al. (2015) discovered the potency of razor clams taken from Madura. Hence, the research on donacid bivalves will be valuable input to the mollusk data of this island. In addition, this paper describes these donacid bivalves and examines their morphological variation that will be useful for taxonomy work.

MATERIALS AND METHODS

Sampling and Preservation

Samples were collected from Nepa Beach, Sampang, Madura, Indonesia. Living bivalves were relaxed by using $MgCl_2.6H_2O$ 7.3% in sea water, and then preserved in Ethanol 70%. Shells were cleaned in fresh water before drying for storage. Exterior and interior of 215 shells was observed carefully under a magnifying lamp.

Identification and Measurement

Specimens were identified based on morphological characters of the shells. Morphometric measurements of the specimens were taken by calipers. Shell length (SL) was defined as the perpendicular distance between the anterior and posterior ends of the shells. Shell height (SH) was measured from the highest part of the dorsal side to the lowest part of the ventral side of the shells. Shell width (SW) was defined as the distance between the most prominence parts of the lateral side of the two shells. Dorsal height (DH) was measured from the highest part of the dorsal side to an imaginary line that was perpendicular between the anterior and posterior ends of the shells. Umbo margin line (UML) was defined as the distance from the highest part of the dorsal side of the shell to the posterior end of the shell. Abbreviations used for collections are: MZB.PEL= bivalves collection of Museum Zoologicum Bogoriense (Research Center for Biology – Indonesian Institute of Science); and RA = collection of author.

Data Analysis

The other morphological characters of the shell such as colour, band pattern, and the shape of the shell, were descriptively analyzed, while the patterns of shell morphometric were analyzed by regression analysis.

RESULTS AND DISCUSSION

Identification placed specimens into two different species of donacid bivalves found in Nepa, northern shores of Madura Island Indonesia, namely *Donax cuneata* and *Donax faba*. Systematic accounts of these two species were described as follows.

Donax (*Latona*) *cuneata,* Linnaeus 1758

Donax cuneata Linnaeus, 1758: 683; Prashad, 1932: 202; Lamprell & Whitehead, 1992: plate 51, 379; Hylleberg & Kilburn, 2002: page 67 (list); Hylleberg & Kilburn, 2003: page 207 (list); Dharma, 2005: plate 108, page 267; Huber, 2010.

Materials examined: 91 specimens including RA133 and MZB.PEL.2100, Indonesia, Madura, northern shore, Nepa, S6º53.673' E113º06.673', Coll. Reni Ambarwati, 15 May 2014.

Shell: thick, compressed, distinctly inequilateral, trigonal-ovate in outline. Shell length to up 31.75 mm; shell height up to 28.1 mm; shell width up to 19.9 mm. Sculpture: smooth with fine concentric lines, radial sculpture distinct at posterior end, forming reticulate scale-like sculpture. Umbo: inflated, prosogyrate. Colour: white, cream, brown, grey; usually with radial bands of varying thickness and prominence; interior white to purple, often with tinted yellow, brown or purple blotch. Dentition: heterodont with anterior and posterior lateral teeth. Interior of the shell: elongated anterior adductor scar and rounded posterior adductor scar; deep palial sinus (approximately ½ of shell length); obvious palial line (Figures 1-2).

Habitat: these bivalves were buried shallowly in the sand of intertidal zone.

***Donax* (*Latona*) *faba* Gmelin, 1791**

Donax faba Gmelin, 1791: 3264; Prashad, 1932: 203; Lamprell & Whitehead, 1992: plate 51, 379; Hylleberg & Kilburn, 2002: page 67 (list); Hylleberg & Kilburn, 2003: page 207 (list); Dharma, 2005: plate 108, page 380; Huber, 2010.

Materials examined: 124 specimens including RA107 and MZB.PEL.2101, Indonesia, Madura, northern shore, Nepa, S6º53.673' E113º06.673', Coll. Reni Ambarwati, 15 May 2014.

Shell: thick, compressed, inequilateral, triagonal-ovate in outline. Shell length up to 26.8 mm; shell height up to 19.9 mm; shell width up to 18.4 mm. Sculpture: surface smooth with fine concentric lines that are usually more pronounced and appear as ridges on the posterior side. Umbo: inflated, prosogyrate. Colour: white, cream, brown, purple; often with one or more radial bands and random wide spots; interior white, often with shaded yellow or with purplish blotches, to purple, usually with whitish blotches and/or radial bands. Dentition: heterodont with anterior and posterior lateral teeth. Interior of the shell: elongated anterior adductor scar and rounded posterior adductor scar; deep palial sinus (approximately ½ of shell length); obvious palial line (Figures 3-4).

Habitat: these bivalves were buried shallowly in the sand of intertidal zone.

Donax cuneata and *Donax faba* can be distinguished on the basis of their morphological characteristics. *Donax cuneata* have radial ridges at the posterior end of the shell which can be seen as reticulate scale-like sculpture, while *D. faba* lack of these

sculpture, but they have fine concentric lines at the posterior and ventral part of the shell. Furthermore, these two bivalves can be differentiated based on their morphometric patterns.

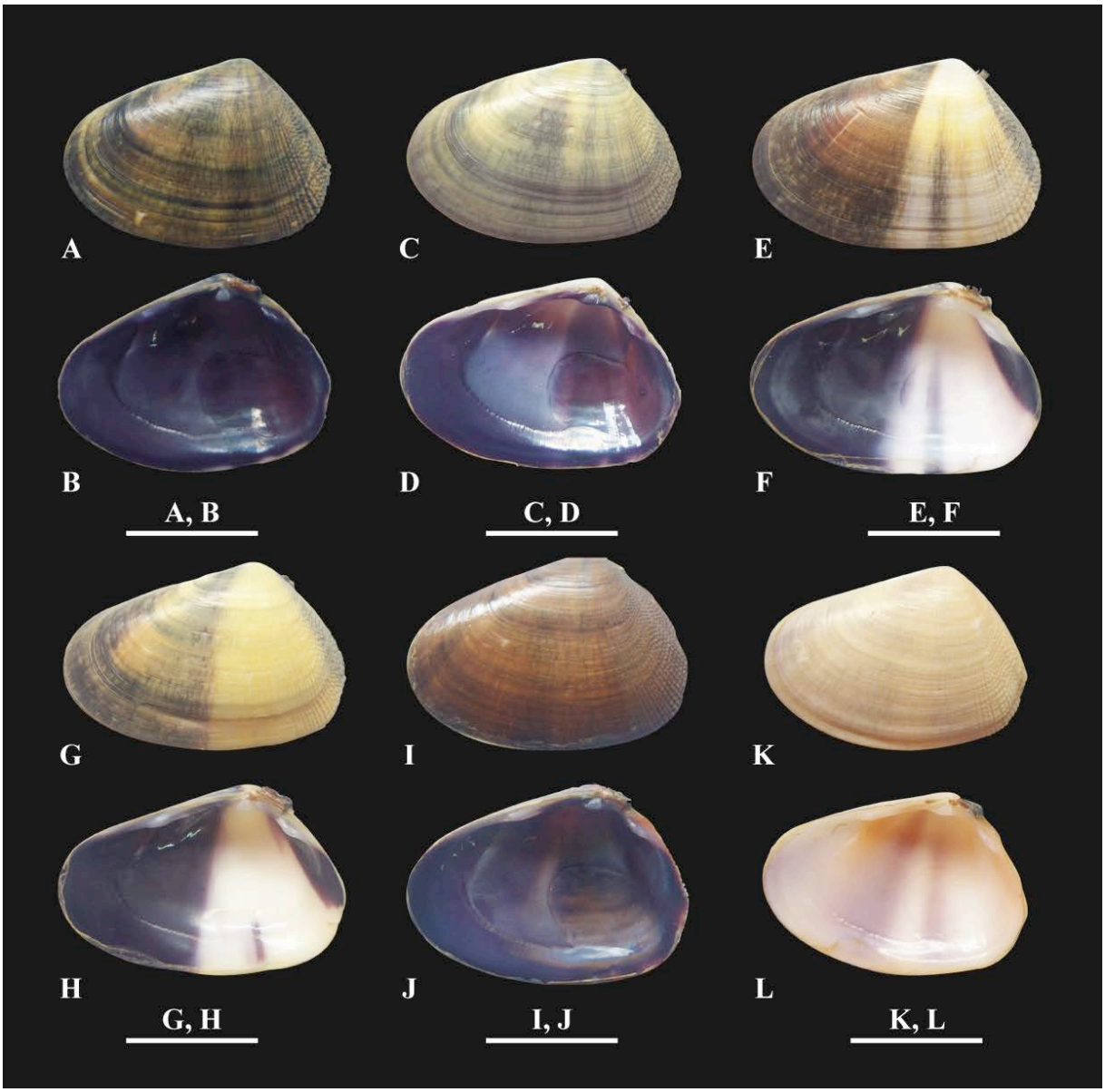

Figure 1. Variation in *Donax cuneata* collected from Madura Island; A,B: Type 1; C,D: Type 2; E,F: Type 3; G,H: Type 4; I,J: Type 5, K,L: Type 6; scale bar: 10 mm.

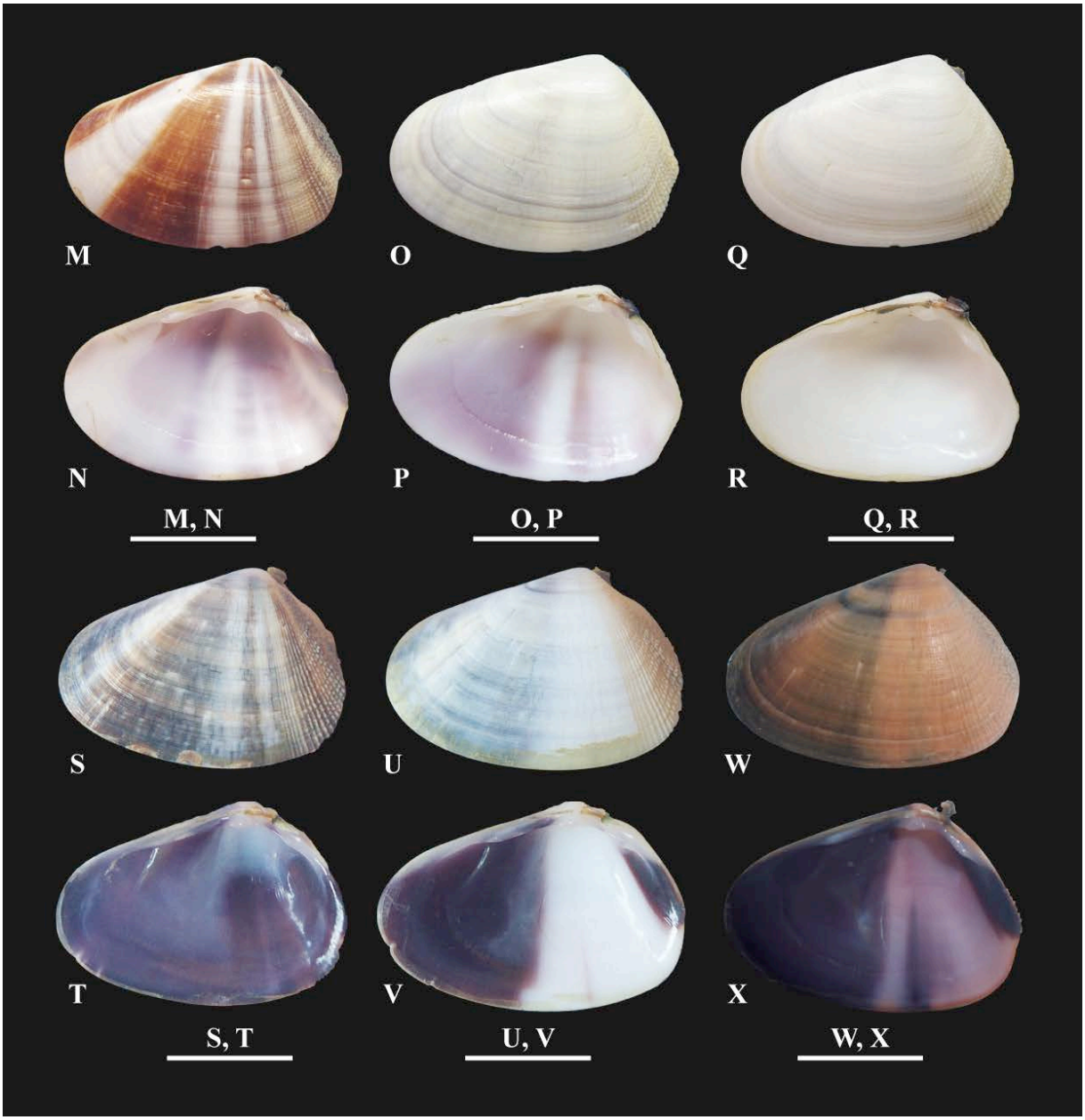

Figure 2. Variation in *Donax cuneata* collected from Madura Island; M,N: Type 7; O,P: Type 8; Q,R: Type 9; S,T: Type 10; U,V: Type 11, W,X: Type 12; scale bar: 10 mm.

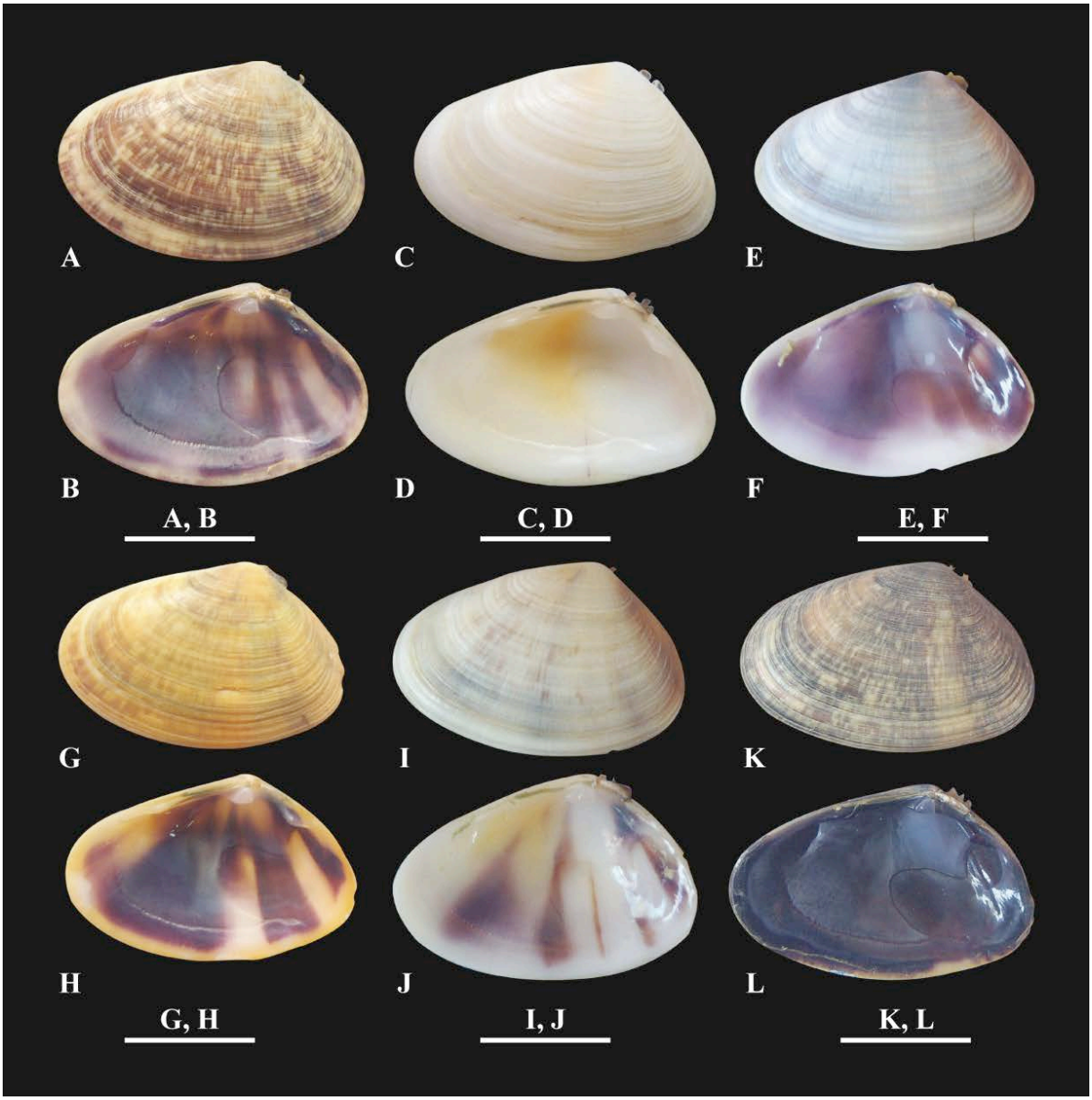

Figure 3. Variation in *Donax faba* collected from Madura Island; A,B: Type 1; C,D: Type 2; E,F: Type 3; G,H: Type 4; I,J: Type 5, K,L: Type 6; scale bar: 10 mm.

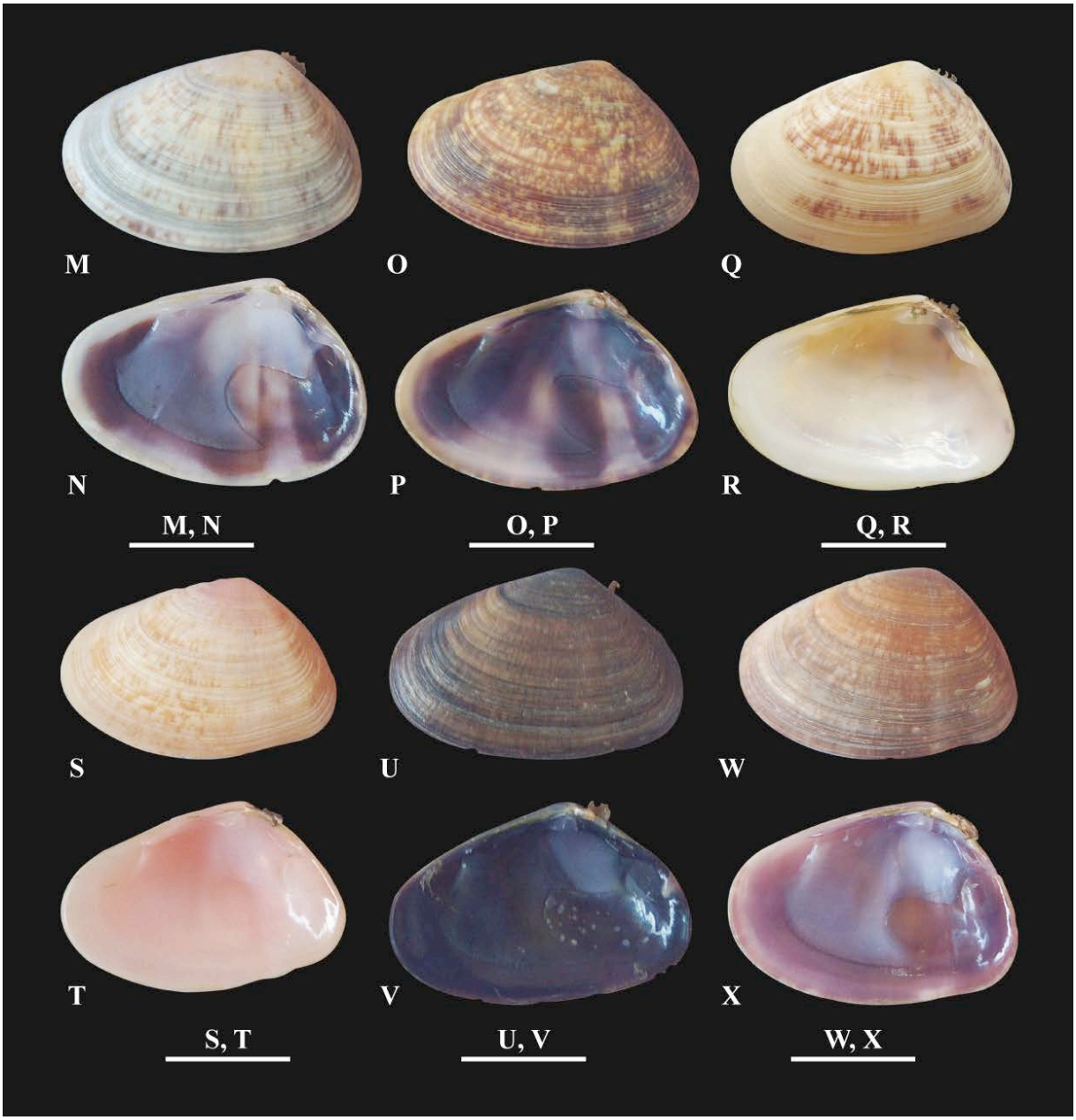

Figure 4. Variation in *Donax faba* collected from Madura Island; M,N: Type 7; O,P: Type 8; Q,R: Type 9; S,T: Type 10; U,V: Type 11, W,X: Type 12; scale bar: 10 mm.

Donax cuneata collected from Madura Island were bigger than *D. faba*. The length of *Donax cuneata* could reach 31.75 mm, while the length of *Donax faba* was up to 26.8 mm. Moreover, the anterior part of the former was more likely to become wider than the latter. In addition, most of *Donax cuneata* shells were thick, and this could be observed in the width of the shells. The shell width of *Donax cuneata* could reach 19.9 mm and the ratio of shell width and shell height (SW/SH) was 0.5, while shell width of *Donax faba* was up to 18.4 mm and

the ratio of shell width and shell height (SW/SH) was 0.48 (Table 1). The relationship of shell height and shell length of *D. cuneata* can be shown by regression equation SH= -1.234+0.772SL, whereas equation for *D. faba* was SH= -4.795+ 0,4795SL. Moreover, the relationship of shell shell width and shell length of *D. cuneata* can be shown by regression equation SW= -2.924+0.482SL, whereas equation for *D. faba* was SW= -0.716+ 0,374SL (Table 1). However, the size and colour of sampled shells collected from Madura Island was highly varied.

Table 1. Comparison of morphometric features of *Donax cuneata* and *Donax faba*

	Donax cuneata	***Donax faba***
Shell length (SL) (mm)	24.52±4.22 (13.5-31.75)	21.27±3.02 (6.6-26.8)
Dorsal height (DH) (mm)	14.80±3.40 (6.8-21.9)	12.06±1.65 (7.2-15.8)
Shell height (SH) (mm)	17.70±3.51 (8.3-24.8)	14.99±1.84 (9.2-19.9)
Distance of Umbo-Anterior Margin (mm)	17.75±3.62 (7.8-25.5)	15.03±2.23 (9.2-20.9)
Shell width (mm)	8.90±2.45 (3.9-19.9)	7.24±2.10 (3.1-18.4)
SW/SL ratio	0.36	0.34
SW/SH ratio	0.50	0.48
SH/SL ratio	0.72	0.71
Relationship SW ×SL	SW= -2.924+0.482SL	SW= -0.716+0.374SL
Relationship SW ×SH	SW= -1.420+0.583SH	SW= -1.797+0.603SH
Relationship SH ×SL	SH= -1.234+0.772SL	SH= -4.795+0.479SL

Note: SW: shell width, SL: shell length, SH: shell height

Both of *Donax cuneata* and *Donax faba* varied among the individual in population, including colour, shape, and size. There were 12 types of colour pattern of *Donax cuneata*. White colour on both exterior and interior was the most frequent pattern in this species and, followed by dark purple with tinted yellow exteriorly and dark purple interiorly (Table 2). Similar with *D. cuneata, D. faba* also were found in 12 types of colour pattern. The pattern of light brown with brown maculation exteriorly and yellow with purple maculation interiorly was the most frequent pattern that could be found, followed by Type 5 which was white exteriorly with brown maculation and the interior was white tinted purple (Table 3).

Table 2. Colour and morphometric variation of *Donax cuneata*

Type	Shell colour	n	SL (mm)	DH (mm)	SH (mm)	UML (mm)	SW (mm)	Ratio		
								SW/ SL	SW/ SH	SH/ SL
Type 1	ext: dark purple with tinted yellow; int: dark purple	19	24.66±4.14	15.35±4.46	18.27±3.38	18.30±3.39	9.14±2.18	0.37	0.50	0.74
Type 2	ext: yellowish purple; int: dark purple	15	23.67±4.54	14.20±3.13	16.76±4.35	16.83±4.34	8.58±3.79	0.35	0.51	0.70
Type 3	ext: half anterior brown, half posterior white with white band; int: half anterior purple, half posterior white with purple band	8	26.40±3.34	15.54±1.82	19.01±2.22	19.13±4.09	9.16±1.56	0.35	0.48	0.72
Type 4	ext: half anterior brown, half posterior yellow with purple band; int: half anterior purple, half posterior white with purple band	1	30.8	19.5	20.9	21.9	11.3	0.37	0.54	0.68
Type 5	ext: brown; int: purple	10	22.17±1.25	12.60±1.64	15.49±1.65	16.19±1.65	8.36±1.50	0.38	0.54	0.70
Type 6	ext: cream; int: cream with purple blotch	4	25.55±5.20	15.55±3.97	19.05±4.44	19.50±3.79	9.48±2.69	0.37	0.49	0.74
Type 7	ext: white with brown radial bands; int: white with purple blocth	4	21.38±6.87	12.05±3.98	14.88±5.35	16.15±6.89	7.40±2.96	0.34	0.49	0.69
Type 8	ext: yellowish white; interior: white with purple blocth	2	27.55±3.46	15.30±0.28	18.25±1.34	20.63±4.14	9.30±0.99	0.34	0.51	0.66
Type 9	ext: white; interior: white	24	25.36±4.34	15.60±3.32	18.61±3.30	17.79±3.20	9.16±2.52	0.36	0.49	0.73
Type 10	ext: purplish brown with white radial band; int: purple	1	19.6	12.5	14.2	15.3	7.2	0.37	0.51	0.72
Type 11	ext: white; int: half anterior purple, half posterior white with purple spot	1	21.6	12.9	14.4	15.8	7.4	0.34	0.51	0.67
Type 12	ext: brown with broad purple band anteriorly; int: dark purple with tinted light purple	2	25.50±0.85	15.70±1.56	18.55±1.91	18.40±1.27	9.45±1.20	0.37	0.51	0.73

Note: n: number of examined shell, SL: shell length, SW: shell width, DH: dorsal height, SH: shell height, UML: umbo margin line, ext: exterior, int: interior.

Table 3. Colour and morphometric variation of *Donax faba*

Type	Shell colour	n	SL (mm)	DH (mm)	SH (mm)	UML (mm)	SW (mm)	Ratio		
								SW/ SL	SW/ SH	SH/ SL
Type 1	ext: light brown with brown maculation; int: yellow with purple maculation	42	21.41±2.95	11.97±1.60	15.10±1.97	15.09±2.06	7.16±1.57	0.34	0.47	0.71
Type 2	ext: white; int: white tinted yellow	6	17.73±5.88	11.72±2.24	14.30±2.20	13.98±2.48	6.22±1.29	0.40	0.43	0.91
Type 3	ext: purplish white; int: purple with white spot at ventral margin	2	21.85±1.48	12.28±1.17	14.80±0.57	15.60±1.41	6.75±0.92	0.31	0.46	0.68
Type 4	ext: yellow with brown maculation; int: purple with yellow spot	6	24.08±1.65	12.94±1.23	16.49±1.68	17.63±2.38	9.05±2.79	0.38	0.55	0.68
Type 5	ext: white with brown maculation; int: white tinted purple	26	20.69±2.11	11.78±1.62	14.77±1.74	14.41±1.88	6.42±1.00	0.31	0.44	0.71
Type 6	ext: purplish brown; int: dark purple	9	20.82±3.45	11.82±1.24	14.57±1.39	14.48±2.21	6.72±1.44	0.32	0.46	0.71
Type 7	ex: white with brown maculation; int: purple tinted white at ventral margin	2	21.80±0.14	12.35±1.77	15.30±1.27	15.85±0.92	7.65±1.48	0.35	0.50	0.70
Type 8	ext: brown with cream maculation; int: purple tinted white at ventral margin	4	23.15±1.50	12.13±1.20	15.99±0.90	15.78±2.67	7.51±1.01	0.33	0.47	0.69
Type 9	ext: cream with brown maculation; int: cream	20	21.19±2.95	12.21±1.94	14.59±1.91	15.12±2.24	7.94±3.42	0.37	0.53	0.69
Type 10	ext: pinkish cream with brown maculation; int: pinkish cream	3	22.23±3.52	13.07±2.51	15.87±2.36	15.67±2.53	7.72±2.03	0.34	0.48	0.71
Type 11	ext: dark brown; int: dark purple	3	21.85±0.97	11.87±0.31	14.07±0.61	12.97±1.76	9.27±4.53	0.42	0.65	0.64
Type 12	ext: brown; int: light purple	1	25.9	15.8	18.1	20.9	9.1	0.35	0.50	0.70

Note: n: number of examined shell, SL: shell length, SW: shell width, DH: dorsal height, SH: shell height, UML: umbo margin line, ext: exterior, int: interior.

Colour and pattern of *Donax cuneata* and *Donax faba* were almost the same, however they had different tendency in pattern. *Donax cuneata* were usually dominant in dark purple and white shell, often found with radial band; while the latter were frequently found in cream shell with random brown maculation formed "batik" pattern. In addition to colour, *Donax cuneata* and *D. faba* could be distinguished on the basis of their sculpture of the shell. *Donax cuneata* had prominence radial ribs at the posterior side, on the other hand *D. faba* only had strong concentric line at this side. This was also confirmed by Tan & Low, (2013).

Moreover, the shapes of these two species were different. Although *Donax cuneata* and *Donax faba* were in common shape known as "wedge" (McLachlan et al., 1995) because the average ratio of shell width and shell length were 0.36 and 0.34 respectively, their shapes were not the same. The posterior side of *D. cuneata* was rounded, while posterior side of *D. faba* was often found elongated to the ventral side, such as found in the Type 2, 3, 6, 9, 10, and 12. In addition, *D. cuneata* looked more inequilateral since the umbo margin line was longer (Table 1). The shell *Donax faba* looked more slender than *D. cuneata* because the ratios of shell width and shell length as well as the ratio of shell width and shell height of *D. faba* are smaller than *D. cuneata*. This nature of the shell facilitated their burrowing activities in the sandy beach. Stanley, (1970) explained that the wedge-shaped of donacid bivalves was an adaptation for fast burrowing and movement between tide-levels.

There was high variation among the individual of *D. cuneata* collected from Madura Island that could be grouped into 12 types of variation. Previously Tan & Low (2013) had reported this kind of variation among the individuals from Singapore. Among the individual collected from Madura Island, Type 5, which was white exteriorly and interiorly, was the most dominant, followed by Type 1 with dark purple appearance. The morphometric of those types were varied, however, generally they revealed wedge-shaped appearance, namely the ratio of SW/SL ranged 0.34-0.38, the ratio of SW/SH ranged 0.49-0.54, and the ratio of SH/SL was 0.66-0.74.

The similarly high variation was also found among the individual of *D. faba* collected from the same site. Dharma (2005) also recorded five-shell variation of *D. faba* collected from Panimbang, West Jawa, Indonesia. Previous study also reported the variation of *D. faba* in Singapore (Tan & Low, 2013). Among the individual collected from Madura Island, Type 1, which has "batik" appearance (the exterior is light brown with brown maculation) was the most dominant. The morphometric characters of *D. faba* types were also varied, however,

generally they revealed slender wedge-shaped appearance, namely the ratio of SW/SL ranged 0.31-0.4, the ratio of SW/SH ranged 0.43-0.65, and the ratio of SH/SL was 0.64-0.70.

Various coloration of *Donax faba* and *Donax cuneata* often lead to misidentification. This research discovered quantitative as well as qualitative variation of those two species, which has been described completely in this paper. Hence, it will be useful for the identification of donacid bivalves based on morphological characteristics.

CONCLUSION

Donax cuneata and *Donax faba* can be found at Nepa Beach, northern shores of Madura Island, Indonesia. Each of these species has 12 types of shells, based on coloration and morphometric pattern.

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