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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. A population of donacid bivalves had been found in the northern shore of Madura Island, Indonesia. This study aimed to identify the donacids 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 results revealed that there were two species of donacid bivalves in Nepa Beach, namely *Donax cuneata* and *Donax faba* with different morphological characteristics, including twelve different patterns and colours of the shells. These variations were described completely in this paper. This study contributes to the research on bivalve taxonomy, and is useful for the identification of donacid bivalves based on morphological characteristics.

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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* were 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 have been identified. Lamprell & Healy, (1998) identified seven species that belonged 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. incarnates*. 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 *D. cuneata* and *D. faba* has also been reported from other 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 have been 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) included *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 variations 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. They argued that those morphological plasticities related to their habitat condition. Tan & Low (2013) described that Singaporean *Donax cuneata* had white, cream, brown, and grey coloration, and also radial bands pattern. In addition, Tan & Low (2013) also described that *Donax faba* found in Singapore varied in shell shape, and coloration pattern. These findings highlight the possibility that a 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 other 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 data of molluscs of this island. In addition, this paper describes these donacid bivalves and examines their morphological variation that will be useful for taxonomy work.

METHODS

Sampling and Preservation

Samples were collected from Nepa Beach, Sampang, Madura Island, 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 were 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 perpen-

dicular 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 the first author.

Data Analysis

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

RESULTS AND DISCUSSION

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

***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, S6°53.673' E113°06.673', 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, S6°53.673' E113°06.673', 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 shells, 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.

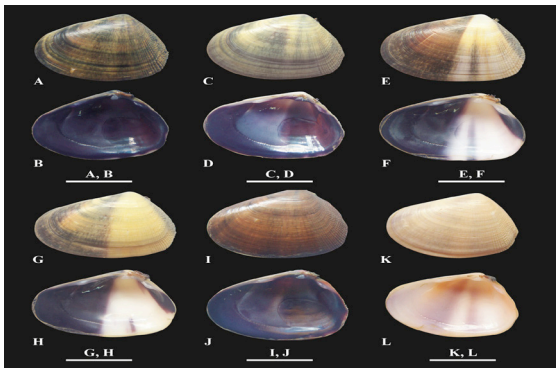

Figure 1. Variation in *Donax cuneata* collected from Madura Island; A,B: Type 1; C,D: Type 2; E,F: Type 3; G,H: Type 4; I,J: Type 5, K,L: Type 6; scale bar: 10 mm.

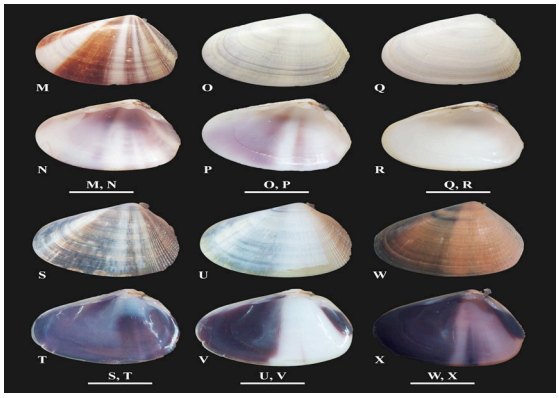

Figure 2. Variation in *Donax cuneata* collected from Madura Island; M,N: Type 7; O,P: Type 8; Q,R: Type 9; S,T: Type 10; U,V: Type 11, W,X: Type 12; scale bar: 10 mm.

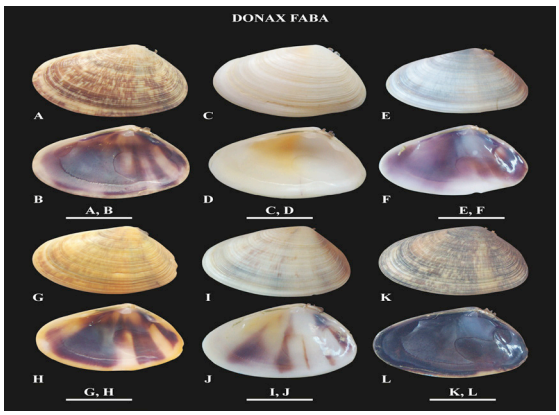

Figure 3. Variation in *Donax faba* collected from Madura Island; A,B: Type 1; C,D: Type 2; E,F: Type 3; G,H: Type 4; I,J: Type 5, K,L: Type 6; scale bar: 10 mm.

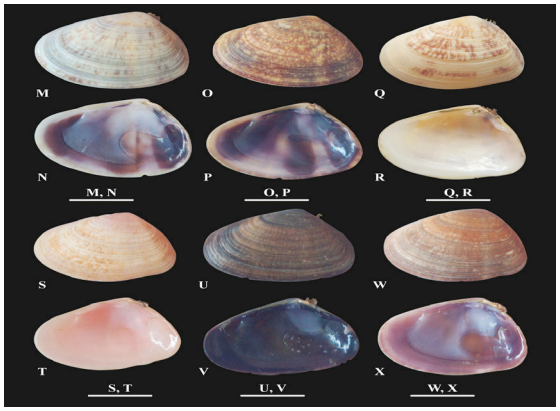

Figure 4. Variation in *Donax faba* collected from Madura Island; M,N: Type 7; O,P: Type 8; Q,R: Type 9; S,T: Type 10; U,V: Type 11, W,X: Type 12; scale bar: 10 mm.

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* was shown by regression equation SW=

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

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.

-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.

Both of *Donax cuneata* and *Donax faba* varied among the individuals in the population, including colour, shape, and size. There were twelve types of colour patterns of *Donax cuneata*. White colour on both the 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* was found in twelve 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).

Colours and patterns of *Donax cuneata* and *Donax faba* were almost the same, however they had different tendency in pattern. The shell of *Donax cuneata* was mostly dark purple and white, often found with radial bands; while *Donax faba* was 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 the sculpture of their shells. The former had prominent radial ribs at the posterior side, while the latter 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* had a 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. However, 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 of *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* were smaller than *D. cuneata*. This nature of the shell facilitated their burrowing activities in the sandy beach. Stanley, (1970) explained that the wedge-shaped shell of donacid bivalves was an adaptation for fast burrowing and movement between tide-levels.

There was high variation among the individuals of *D. cuneata* collected from Madura Island that could be grouped into twelve types of variations. In a previous study, Tan & Low (2013) 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 characteristics of

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.

those types varied, but, generally they revealed a wedge-shaped appearance, namely the range of SW/SL ratio was 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 individuals of *D. faba* collected from the same site. Dharma (2005) also recorded five-shell variation of *D. faba* collected from Panimbang, the Indonesian Province of West Jawa. Previous study also reported the variation of *D. faba* in Singapore (Tan & Low, 2013). Among the individuals collected from Madura Island, Type 1, which had "batik" appearance (the exterior was light brown with brown maculation) was the most dominant. The morphometric characteristics of *D. faba* types also varied, but, they commonly had 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 a 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 the morphological characteristics.

CONCLUSION

Donax cuneata and *Donax faba* were found at Nepa Beach, the northern shores of Madura Island, Indonesia. Each of these species had twelve types of shells, based on coloration and morphometric patterns.

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