BIODIVERSITAS
Volume 24, Number 12, December 2023
Pages: 6684-6691

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d241230

Short Communication: New records of *Mactra* clams (Bivalvia: Mactridae) from Madura Island, Indonesia

CATHERINE BERLIANA WIJAYA[1], RENI AMBARWATI[1,♥], NUR ROHMATIN ISNANINGSIH[2]

[1]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya. C3 Building, 2nd Floor, Unesa Ketintang Campus. Jl. Ketintang, Surabaya 60284, East Java, Indonesia. Tel.: +62-318-296427, ♥email: reniambarwati@unesa.ac.id

[2]Research Center for Biosystematics and Evolution, National Research and Innovation Agency. Jl. Raya Bogor KM. 46, Cibinong, Bogor 16911, West Java, Indonesia

Manuscript received: 13 September 2023. Revision accepted: 24 December 2023.

Abstract. *Wijaya CB, Ambarwati R, Isnaningsih NR. 2023. Short Communication: New records of Mactra clams (Bivalvia: Mactridae) from Madura Island, Indonesia. Biodiversitas 24: 6684-6691.* Mactridae is a family of bivalves found in shallow waters, such as living at high tide lines, in tidal areas, and below low tide lines. More mactrid bivalves could be discovered, and further studies are needed in Indonesian waters. Madura Island has a variety of bivalves, and *Mactra* clams could also be discovered on this island. Therefore, this study aimed to identify *Mactra* clams from Madura Island, Indonesia, and analyze their morphological characters. Samples were collected at Nepa and Badur Beaches during low tides, and then identified based on morphological characteristics. A stereo microscope observation and detailed descriptions were carried out to obtain the qualitative characteristics, while the quantitative ones, included shell length and height, palial line height, and diameter. The environmental parameters of this two-beach were also evaluated. Data were analyzed descriptively. The results showed two new records of Mactridae members at both beaches, namely *Mactra luzonica* Reeve, 1854, *Mactra dissimilis* Reeve, 1854. *Mactra dissimilis* revealed morphological variation, namely in the coloration on both the exterior and interior of the shell. There were three variations of *M. dissimilis*, namely bluish-white shell, brownish-white shell, and white shell. The findings of *M. dissimilis* and *M. luzonica* are regarded as new records for Madura Island, Indonesia.

Keywords: Coastal ecosystem, *Mactra dissimilis*, *Mactra luzonica,* marine invertebrate, morphological variation

INTRODUCTION

Mactridae is a species of bivalve that lives at the bottom of muddy waters, and some of its members can also be found in the mangrove zone (Poutiers 1998; Ambarwati and Trijoko 2015). According to Robin (2011), the habitat ranges from sea to estuary, mainly subtidal and sublittoral, which can sometimes be down to 200 m deep. It is predominantly marine estuaries found in brackish or close to freshwater or swamps and mangrove areas. The organisms are infaunal, burrowing in sandy or muddy substrates, as well as exhibiting shallow burrowing in sandy beaches just below the low tide line and stranding in large numbers.

MolluscaBase eds (2022) listed 56 species of *Mactra* in the worldwide. Dharma (2005) reported three species of *Mactra* from Indonesia, namely *Mactra maculata* Gmelin, 1791; *Mactra grandis* Gmelin, 1791; and *Mactra violacea* Gmelin, 1791. Furthermore, some researchers discovered the existence of these clams. Ginting et al. (2017) confirmed the existence of *M. grandis* in Tanjungbalai Waters, North Sumatra. Similarly, Hidayah and Ambarwati (2021) reported *M. grandis* and *M. violacea* were found in the intertidal zone of Boom Beach, Tuban. Octavina et al. (2019) documented the presence of *M. luzonica* in the Lamnyong River area, Aceh. Lase et al. (2021) further discovered three species in Muara Saragian, Aceh Singkil District, namely *M. dissimilis*, *M. grandis* and *M. violaceae*. Additionally, Ambarwati and Trijoko (2015) reported *Mactra queenslandica* E.A.Smith, 1914 from Sidoarjo Coastal Waters, East Java, which is a new record for Indonesian waters.

Mactra clams are reported to have morphological variation, especially in the coloration. For instance, *Mactra abbreviata* Lamarck, 1818, *Mactra achatina* Holten, 1802, *Mactra cygnus* Gmelin, 1791, *Mactra deshayesi* Mayer, 1867 and *Mactra luzonica* Reeve, 1854 (Huber 2010). Furthermore, Lamprell and Whitehead (1992) also reported the variation of *M. dissimilis*. The information on the morphological variation is vital because it can lead to misidentification (Ambarwati and Faizah 2017).

Morphological analysis of bivalve shells plays an important role in various fields such as taxonomy, evolution, functional anatomy, or fisheries management. In general, the shell is the most noticeable and diversified body part (Signorelli et al. 2013). Variations in morphological and behavioral characteristics within species are believed to be determined by changes in physical and/or biological environment. Behavioral differences were also detected among species inhabiting different coastal zones (Chetoui et al. 2012). Genetic variation and phenotypic plasticity due to different environmental constraints can cause variations in the morphology of a population (Vieira et al. 2016). Previous studies have found similar relationships between environmental changes and morphological variation (Guan et al. 2022).

According to Baldi et al. (2017), morphological characteristics are considered one of the simplest, fastest, and most commonly used methods for identification. In this case, the more similar the characteristics of a group of organisms, the closer the relationship, and vice versa. Similarities between species in the *Mactra* genus lead to difficulty in distinguishing one member from another.

Recent observations found a population of Mactra clams on the northern shore of Madura Island, Indonesia. Previous publications reported the occurrence of various bivalves on the beaches of this island. Ambarwati and Irawan (2020), revealed the diversity of bivalves on the northern shore of Madura Island. Meanwhile, Ambarwati and Faizah (2017) and Ambarwati et al. (2021) reported the occurrence of some bivalves on the northern shore of Madura. However, until now, there has been no publication concerning the existence and morphological variations of *Mactra* shells on Madura Island. Therefore, this study aimed to identify *Mactra* clams from Madura Island, Indonesia, and analyze their morphological characteristics.

MATERIALS AND METHODS

Study area and materials

Samples were collected from two locations, namely Nepa Beach, Sampang District (6°53'58"S 113°12'03"E) and Badur Beach, Sumenep District (6°52'42"S 113°58'46"E), Madura Island, East Java Province, Indonesia (Figure 1). Morphological identification was then carried out at the Laboratory of Animal Taxonomy, Universitas Negeri Surabaya, Indonesia. The voucher specimens are deposited in the Malacological Collection of Museum Zoologicum Bogoriense (MZB), Indonesia.

Procedures

The *Mactra* clams were selected with a purposive sampling technique, and their shells were collected from the bottom of the water or inside substrates by digging using a trowel. The shells were then sorted and identified according to the identification books of Huber (2010) and Lamprell and Whitehead (1992). Qualitative and quantitative characteristics of the organisms were determined through morphological observation. A stereo microscope and detailed descriptions were employed in obtaining the qualitative characteristics, while the quantitative ones, including shell length and height, palial line height and diameter (Ambarwati and Trijoko 2015), palial sinus diameter, plus posterior and anterior adductor scar diameter, were measured with caliper. Meanwhile, the qualitative characteristics were shell shape, color, and carving, ligament color, muscle attachment marks, umbo location, umbo color, palial lines and sinuses, as well as the number of cardinal teeth (Wong 2009).

The environmental parameters were also measured during the sample collection. The substrate was evaluated based on visual observation. pH of water was measured by using pH pen digital. Water salinity was measured by using hand refractometer. In addition, the water temperature was measured by using water thermometer.

Data analysis

Data were analyzed descriptively, both quantitative and qualitative.

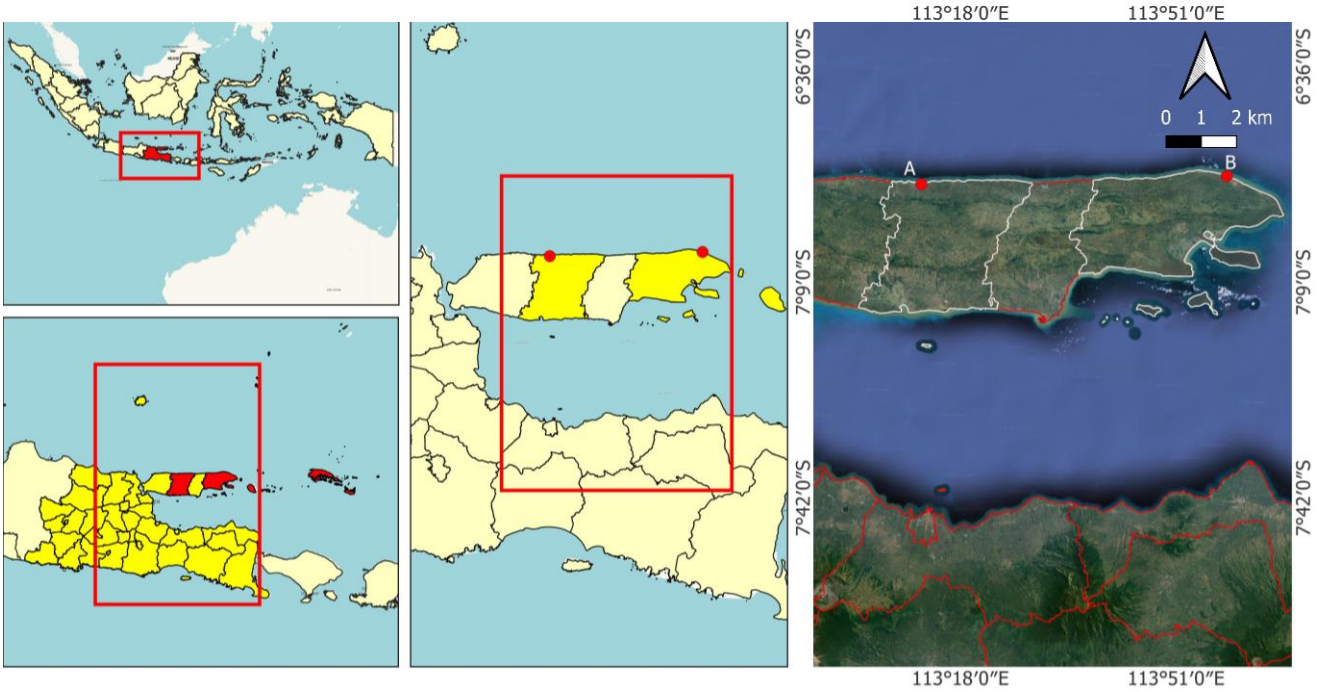

Figure 1. Sampling locations on Nepa and Badur Beaches, Madura Island, Indonesia. A. Nepa Beach, Sampang District; B. Badur Beach, Sumenep District

RESULTS AND DISCUSSION

Systematics and description

Based on the sampling results, two *Mactra* species were found on Nepa Beach, Sampang District, Madura, namely *Mactra luzonica* Reeve, 1854 and *Mactra dissimilis* Reeve, 1854, and their variations are presented in Figure 2 and Figure 3.

Mactra luzonica Reeve, 1854

Material examined. Three specimens were collected from Nepa Beach, including MZB PEL 2.242; eight specimens were collected from Badur Beach, including MZB PEL 2.246.

Description. *Mactra luzonica* has an oval-shaped, purplish blue exterior and interior and a finely carved shell with a 14.1 mm length, 10.4 mm height, and 7.1 mm width. The ligaments seen are brown, while the umbo stands out and it appears blue. The pallial line is clearly visible. The pallial sinus is shallow. The posterior adductor muscle scars are wider than the anterior adductor muscle scars. Hinge with an inverted v-shaped paired of cardinal teeth in the left valve (LV), right hinge with two lateral teeth (LAI and LAIII), different in length, the LAI more elongated than the LAIII, Chondrophore (Ch) or resilifer wide, triangular in shape; posterior lateral teeth more elongated than the anterior, similar in size and shape; cardinal teeth not fused (Figures 3A and 3B) at the dorsal side of Chondrophore, with the anterior short and strong, oriented obliquely to the anterior side of the shell and the posterior slender, fragile and placed almost vertically. Left hinge with one anterior and one posterior lateral teeth (LAII and LPII), almost similar in size but anterior lateral teeth (LAII) slightly larger, thick, and strong; two single cardinal teeth fused forming the typical inverted v-shaped (Figure 3).

Habitats. *Mactra luzonica* is found within sandy beach substrates in the intertidal zone of Nepa Beach, Sampang District, Madura. The environmental parameters are water pH of around 7.87, 2‰ salinity, 32°C water temperature, and substrate humidity at low tide is 10 (humid). In Badur Beach, Sumenep District, Madura, *M. luzonica* is found inside muddy beach sand substrates. The environmental parameters are water pH around 7.80, 3‰ salinity, 30°C water temperature, and substrate humidity at low tide is around 10 (humid).

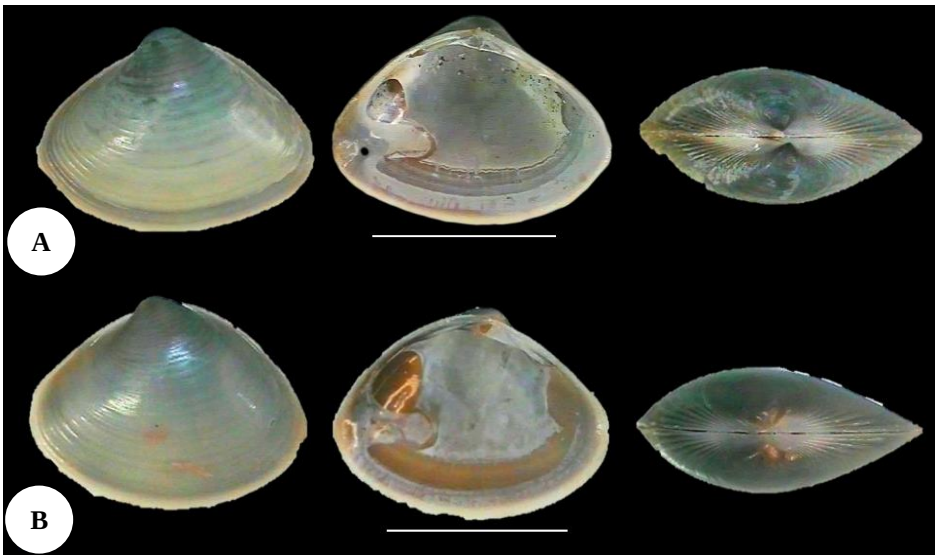

Figure 2. *Mactra luzonica*: A. *M. luzonica* from Nepa Beach, Madura; B. *M. luzonica* from Badur Beach, Madura

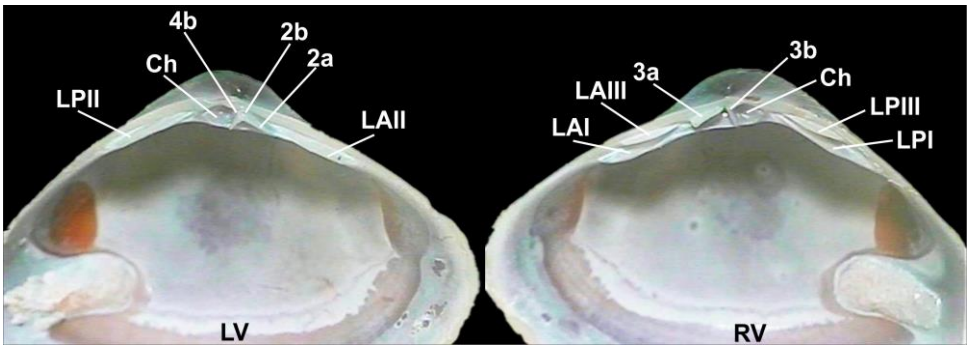

Figure 3. Dentition of *Mactra luzonica*

***Mactra dissimilis* Reeve, 1854 morphs type 1**

Material examined. Ten specimens, including MZB PEL 2.243

Description. *Mactra dissimilis* has a trigonal-shaped, bluish-white shell carved in the form of strong concentric lines, with a 28.6 mm length, 19.7 mm height, and 12.2 mm width. The ligaments are black, while the umbo is inflated and blue. The pallial line is clearly visible. The palial sinus is shallow. The posterior adductor muscle scars are wider than the anterior adductor muscle scars (Figure 4). The dentition pattern is described in Figure 5.

Habitats. *Mactra dissimilis* species is found within sandy beach substrates in the intertidal zone of Nepa Beach, Sampang District, Madura. The environmental parameters are water pH around 7.87, 2‰ salinity, 32°C water temperature, and substrate humidity at low tide is 10 (humid).

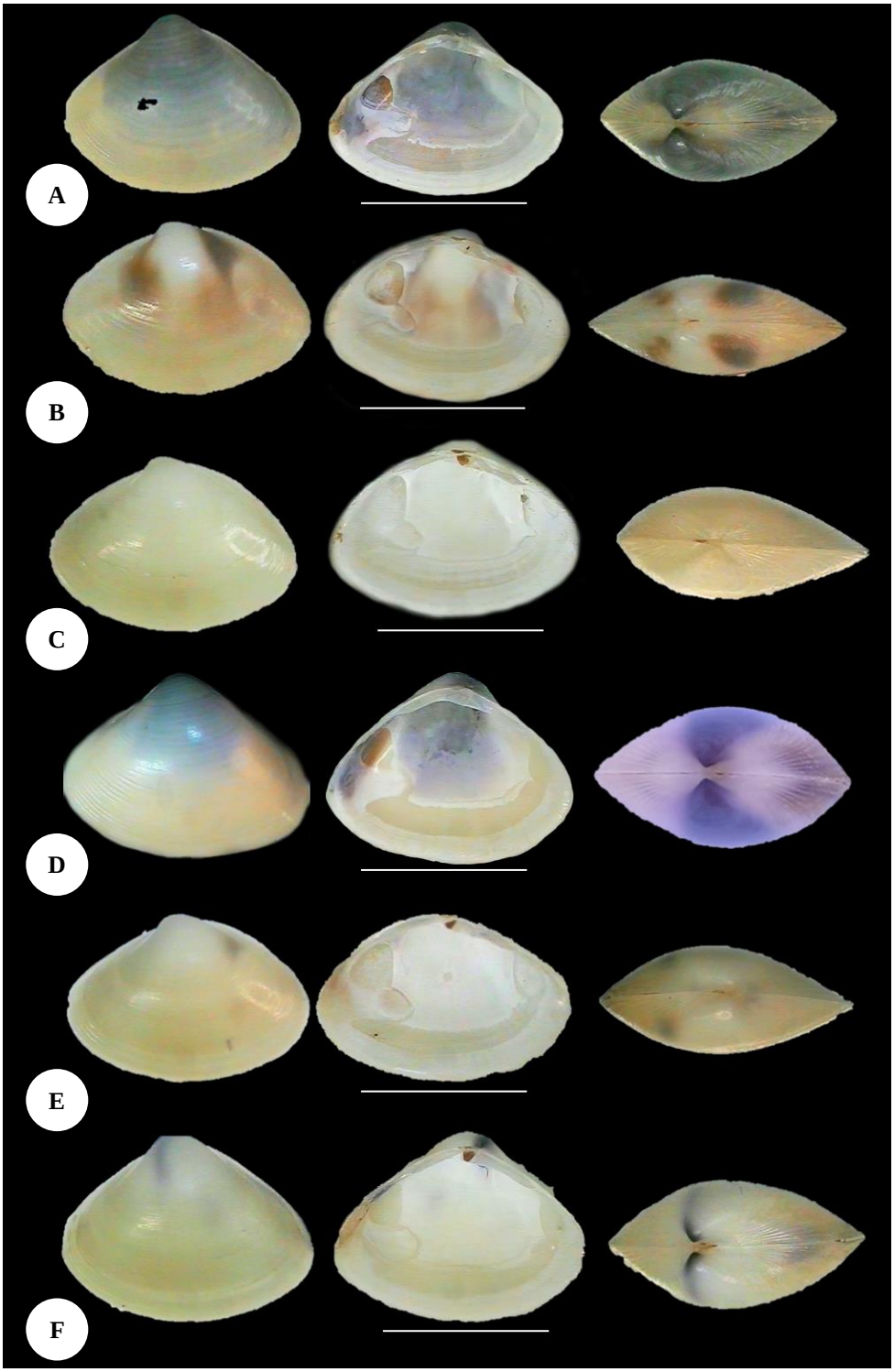

Figure 4. *Mactra dissimilis* from Nepa Beach and Badur Beach, Sampang District, Madura; A-F: Morphs type 1-6

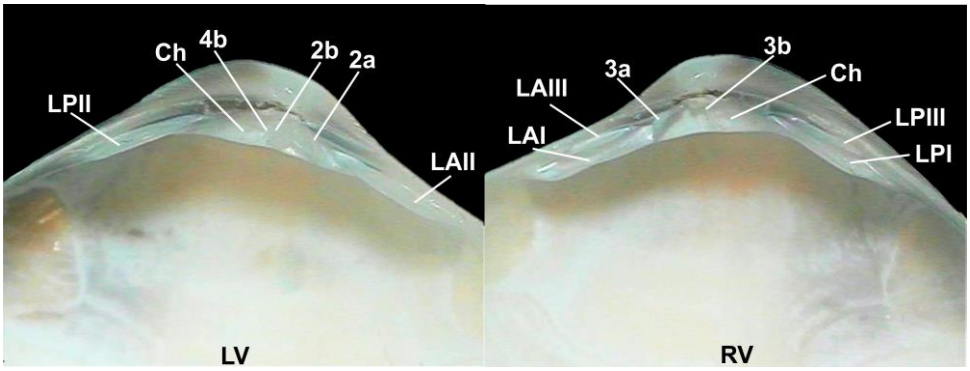

Figure 5. Dentition of *Mactra dissimilis*

***Mactra dissimilis* Reeve, 1854 morphs type 2**

Material examined. Thirteen specimens, including MZB PEL 2.244

Diagnosis. *Mactra dissimilis* has a trigonal-shaped brownish-white shell carved in the form of strong concentric lines with an 18.7 mm length, 14.2 mm height, and 9.3 mm width. The ligaments are brown, while the umbo is inflated and white. The pallial line is clearly visible. The palial sinus is shallow. The posterior adductor muscle scars are wider than the anterior adductor muscle scars (Figure 4). The dentition pattern is described in Figure 5.

Habitats - *Mactra dissimilis* species is found inside sandy beach substrates in the intertidal zone of Nepa Beach, Sampang District, Madura. The environmental parameters are water pH of around 7.87, 2$^{o}/_{oo}$ salinity, 3.2°C water temperature, and substrate humidity at low tide is around 10 (humid).

***Mactra dissimilis* Reeve, 1854 morphs type 3**

Material examined. Two specimens, including MZB PEL 2.245

Diagnosis. *Mactra dissimilis* has a trigonal-shaped white shell carved in the form of strong concentric lines, with a 20.4 mm length, 13.2 mm height, and 6.2 mm width. The ligaments are brown, while the umbo is inflated and appears white. The pallial line is clearly visible. The palial sinus is shallow. The posterior adductor muscle scars are wider than the anterior adductor muscle scars (Figure 4). The dentition pattern is described in Figure 5.

Habitats. *Mactra dissimilis* species is found within sandy beach substrates in the intertidal zone of Nepa Beach, Sampang District, Madura. The environmental parameters are water pH around 7.87, 2$^{o}/_{oo}$ salinity, 32°C water temperature, and substrate humidity at low tide is 10 (humid).

Based on the sampling results, there were also two species of *Mactra* were found on Badur Beach, Sumenep District, Madura, namely *M. luzonica* (Reeve, 1854) and *M. dissimilis* (Reeve, 1854), while their variations are presented in Figure 3.

***Mactra dissimilis* Reeve, 1854 morphs type 4**

Material examined. Thirty-three specimens including MZB PEL 2.247

Diagnosis. *Mactra dissimilis* has a trigonal-shaped purplish white shell carved in the form of strong concentric lines, with a 26.2 mm length, 18.2 mm height, and 11.1 mm width. The ligaments are black, while the umbo is inflated and blue. The pallial line is clearly visible. The palial sinus is shallow. The posterior adductor muscle scars are wider than the anterior adductor muscle scars (Figure 4). The dentition pattern is described in Figure 5.

Habitats. *Mactra dissimilis* species is found inside muddy beach sand substrates in Badur Beach, Sumenep District, Madura. The environmental parameters are water pH around 7.80, 3$^{o}/_{oo}$ salinity, 30°C water temperature, and substrate humidity at low tide is 10 (humid).

***Mactra dissimilis* Reeve, 1854 morphs type 5**

Material examined. Forty-two specimens, including MZB PEL 2.248

Diagnosis. *Mactra dissimilis* has a trigonal-shaped, light brownish-white shell carved in the form of strong concentric lines, with a 26.4 mm length, 18.4 mm height, and 10.4 mm width. The ligaments are brown, while the umbo is inflated and blue. The pallial line is clearly visible. The palial sinus is shallow. The posterior adductor muscle scars are wider than the anterior adductor muscle scars (Figure 4). The dentition pattern is described in Figure 5.

Habitats. Species are found within muddy beach sand substrates in Badur Beach, Sumenep District, Madura. The environmental parameters are water pH around 7.80, 3$^{o}/_{oo}$ salinity, 30°C water temperature, and substrate humidity at low tide is 10 (humid).

***Mactra dissimilis* Reeve, 1854 morphs type 6**

Material examined. Twenty-eight specimens, including MZB PEL 2.249

Diagnosis. *Mactra dissimilis* has a trigonal-shaped white with a purple band at the umbo region shell carved in the form of strong concentric lines, with a 16.4 mm length, 9.1 mm height, and 12.7 mm width. The ligaments are brown, while the umbo is inflated and blue. The pallial line is clearly visible. The palial sinus is shallow. The posterior adductor muscle scars are wider than the anterior adductor muscle scars (Figure 4). The dentition pattern is described in Figure 5.

Habitats. *Mactra dissimilis* species is found within muddy beach sand substrates in Badur Beach, Sumenep

District, Madura. The environmental parameters are water pH around 7.80, 3‰ salinity, 30°C water temperature, and substrate humidity at low tide is 10 (humid).

All morph types of *M. dissimilis* have the same dentition pattern. Hinge with an inverted v-shaped paired of cardinal teeth in the left valve (LV), right hinge with two lateral teeth (LAI and LAIII), different in length, the LAI more elongated than the LAIII, Chondrophore (Ch) or resilifer wide, triangular in shape; posterior lateral teeth more elongated than the anterior, similar in size and shape; cardinal teeth not fused (3A and 3B) at dorsal side of Chondrophore, with the anterior short and strong, oriented obliquely to the anterior side of the shell and the posterior slender, fragile and placed almost vertically. Left hinge with one anterior and one posterior lateral teeth (LAII and LPII), almost similar in size but anterior lateral teeth (LAII) slightly larger, thick, and strong; two single cardinal teeth fused forming the typical inverted v-shaped (Figure 4).

Discussion

The sampling results obtained at the two Beaches showed 139 individuals *Mactra* shells and five identified variations in patterns and colors. On Nepa Beach, 28 individuals *Mactra* shells were found, which can be identified as two species, namely *M. luzonica* and *M. dissimilis*. Meanwhile, 111 individuals were discovered at Badur Beach, belonging to two species, namely *M. luzonica* and *M. dissimilis.* Based on these findings, it can be seen that the *Mactra* clams at Badur Beach were more abundant. According to Huber (2010), *M. luzonica* is distributed in Malaysia and Vietnam. Hence, this finding confirms the occurrence of this clam in Indonesian waters, especially in Madura Island. However, the size of *M. luzonica* from Madura Island is smaller than that reported by Lamprell and Whitehead (1998) and Huber (2010). Meanwhile, the distribution of *M. dissimilis* is in Australian waters (Lamprell and Whitehead 1998; Huber 2010) and they were reported in bigger size (55 mm). In addition to differences in size, there are also differences in habitat. According to Huber (2010) and Lamprell and Whitehead (1998), *M. dissimilis* was found in the subtidal, whereas in this study, they were found in the upper intertidal.

According to Zhang et al. (2022), the substrate is the significant factor that influences the life of benthic mollusks in the mudflat. One very important factor is the substrate, which is a habitat or place to live. For the zoobenthos, the substrate is one of the decisive factors in their habitat selection process, and the substrate environment significantly affects their growth, survival, distribution, and habitat. Badur Beach has a muddy sand substrate, while a sandy and muddy bottom substrate is known to be suitable for *Mactra* clams (Lamprell and Whitehead 1992).

In this study, four variations were detected at both beaches. The first variation is the *M. luzonica*, with a blue umbo and shell exterior. The second is *M. dissimilis* with a white shell exterior and blue umbo color. The third is *M. dissimilis* with a white umbo and shell exterior, as well as brownish spots. The fourth is *M. dissimilis,* with a white umbo and shell exterior. All of the variations have the same dentition pattern (Figures 3 and 5). The description of dentition pattern refers to Hafiz et al. (2021).

Signorelli et al. (2013) reported the relationship between size and shape in *M. isabelleana* which was detected to show variations in shape depending on size. In natural systems, organisms face several ecological challenges that cause phenotypic shifts. Therefore, the interaction between environmental parameters and genotype greatly influences an organism's phenotype. According to Signorelli et al. (2013), salinity plays an important role in the morphological variation of *M. isabelleana* d'Orbigny, 1846.

According to the Minister of Environment Decree No. 51 of 2004, the quality standard for salinity is 0-34‰. Both locations have relatively low salinity values, namely 2‰ at Nepa Beach and 3‰ at Badur Beach. The low values are due to the study location being close to residential areas and the river mouth, which affects the amount of freshwater input. These are also influenced by the intensity of evaporation and sea tides. The salinity in each region varies according to the water conditions. Bakri et al. (2020) stated that the effect of salinity in the waters can cause a decrease in oxygen concentrations, including those found in rivers. The salinity would decrease in line with the increase of the distance toward the headwaters of the river. The salinity would also decrease in the same trends with increasing distance towards the surface of the river.

According to Suhanda et al. (2019), the presence of bivalves is strongly influenced by biotic and abiotic factors. The factor biotic component is food for macrozoobenthos, and the abiotic component is affected by physical-chemical water, including temperature, dissolved oxygen (DO), depth, salinity, substrate, and content of nitrogen (N). According to Baderan et al. (2019) the optimum temperature for bivalvia ranges from 20-30°C. If the temperature is above 32°C, the metabolic process will be interrupted. If the temperature is higher than the optimum one, it is not suitable for its growth. The change of the temperature beyond the limit of the optimum one will affect the decrease of growth and organism reproduction. The Badur Beach temperature is quite low and more suitable for Mactra clams' survival compared to the 30°C in Nepa Beach.

The next factor affecting bivalves' existence is the degree of acidity. The ideal degree of acidity (pH) for the growth of marine biota is 7-8. The degree of acidity on Nepa Beach is higher than Badur Beach. This is because the sampling station is near the landfill where household wastes such as detergent, shampoo soap, etc. are dispersed into the sea. Herawati et al. (2020) stated that the pH value that supports the life of macrozoobenthos, in particular from the phylum Mollusca, is 5.7-8.4. Therefore, *Mactra* clams can still survive at the two beach locations, but Badur is considered more suitable due to having a lower degree of acidity, namely 7.8.

Based on the identification results, there are three *M. dissimilis* variations, which dominate at both locations. This species has a high morphological variation compared to *M. luzonica.* Morphological variations of *Mactra* shells

at the two locations were white umbo with a blue shell, white umbo with white shell color and brownish motifs, and white umbo with white shell. In the study by Irham et al. (2020), *M. dissimilis* occupied one of the highest dominance indices recorded due to the muddy sand environmental conditions that are in accordance with the required type of habitat. According to Holtappels et al. (2013) the high value of the diversity index is influenced by the substrate, temperature, salinity, acidity, and DO. Benthos organisms, especially macrozoobenthos, have a range of tolerances to be able to live well in certain aquatic places where the physical and chemical factors of the area are suitable for them to survive.

Among all, main and supporting characteristics were observed in this current study. According to Jost (2017) a character can be defined as a characteristic of a taxon that can differentiate it from others. Characters are influenced by many factors, for example, structural and functional development.

Characteristics that are strong and can be used to distinguish one *Mactra* species from another include shell carving and color. The shell of *M. dissimilis* is carved in the form of strong concentric lines, while that of *M. luzonica* is finely carved. Moreover, Signorelli et al. (2013) differentiated the morphological variations of *M. isabelleana* using shell characteristics as a major requirement to be considered.

Recent publications reported the occurrence of *M. luzonica* in Malaysia and Vietnam. For example, from Digha Coast, Bay of Bengal (Ramakrishna 2010; Rao 2017; Tudu et al. 2017); Budhabalanga Estuary, Odisha India (Gurumayum 2019); Lamyong River, Aceh (Octavina et al. 2019); Krueng Cut Estuary, Banda Aceh (Irham et al. 2017) (Irham et al. 2020) southwest coast of India (D'Souza and Shenoy 2020); Sonadia Island, Bangladesh (Antu et al. 2023). In addition, the distribution of *M. dissimilis* also reaches Digha coast, Bay of Bengal (Tudu et al. 2017) Krueng Cut Estuary, Banda Aceh (Irham et al. 2017, 2020).

The findings of *Mactra luzonica* and *Mactra dissimilis* in Madura Island, Indonesia, are regarded as new records for this region. This study also reported detail variations of the two species. Further studies on the molecular characterization of this clam are recommended.

ACKNOWLEDGEMENTS

The authors are grateful to the sampling team for helping during the work field.

REFERENCES

Ambarwati R, Faizah U. 2017. Colour and morphometric variation of donacid bivalves from Nepa Beach, Madura Island, Indonesia. Biosaintifika: J Biol Biol Edu 9 (3): 466-473. DOI: 10.15294/biosaintifika.v9i3.11267.

Ambarwati R, Irawan B. 2020. The population of *Solen* sp. (Bivalvia: Solenidae) from Pamekasan, Indonesia. Ecol Environ Conserv 26: S199-S204.

Ambarwati R, Purnomo T, Fitrihidajati H, Rachmadiarti F, Rahayu DA, Faizah U. 2021. Morphological variations of *Meretrix* sp. from Bancaran, Madura, Indonesia. Adv Eng Res 209: 214-217. DOI: 10.2991/aer.k.211215.040.

Ambarwati R, Trijoko. 2015. New records of two mactrid bivalves (Bivalvia: Mactridae) from Indonesia. Treubia 42 (523): 1. DOI: 10.14203/treubia.v42i0.554.

Antu DR, Islam TT, Ahmed R, Ahmed S, Datta K, Ahmed S. 2023. Diversity of bivalves and gastropods in Sonadia Island, Bangladesh. Biores Com 9 (1): 1225-1236. DOI: 10.3329/brc.v9i1.63603.

Baderan DWK, Hamidun MS, Utina R, Rahim S, Dali R. 2019. The abundance and diversity of mollusks in mangrove ecosystem at coastal area of North Sulawesi, Indonesia. Biodiversitas 20 (4): 987-993. DOI: 10.13057/biodiv/d200408.

Bakri B, Sumakin A, Widiasari Y, Ihsan M. 2020. Distribution pattern of water salinity analysis in Jeneberang River estuary using ArcGIS. IOP Conf Ser: Earth Environ Sci 419 (1). DOI: 10.1088/1755-1315/419/1/012116.

Baldi R, Sauthier DEU, Gatto A, Pazos GE, Avila LJ. 2017. Late Cenozoic of Península Valdés, Patagonia, Argentina (P. Bouza & A. Bilmes (eds). 1st ed. Springer, Cham. DOI: 10.1007/978-3-319-48508-9.

Chetoui I, El Cafsi M, Boussaid M. 2012. Allozymic and morphological variation in three populations of surf clam *Mactra corallina* (Bivalvia: Mactridae) from Tunisian sandy beaches. Cahiers de Biologie Marine 53 (4): 409-417. DOI: 10.13140/RG.2.1.3902.4081.

D'Souza SL, Shenoy KB. 2020. Seasonal variation in diversity of intertidal molluscs from Uttara Kannada Coast, Southwest Coast of India. In: Nandan SB, Priyaja P, Jayachandran PR (eds). Frontiers in Benthic Science. Directorate of Public Relations and Publications, CUSAT, Kochi, India.

Dharma B. 2005. Recent and Fossil Indonesian Shells. Conchbooks, Hackenheim.

Ginting EDD, Susetya IE, Patana P, Desrita D. 2017. Identification of the species of bivalves in Tanjungbalai Waters, North Sumatra Province. Acta Aquat: Aquat Sci J 4 (1): 13. DOI: 10.29103/aa.v4i1.318. [Indonesian]

Guan C, Zhao X, Qu T, Zhong Y, Hou C, Lin Z, Xu J, Tang X, Wang Y. 2022. Physiological functional traits explain morphological variation of *Ulva prolifera* during the drifting of green tides. Ecol Evol 12 (1): 1-14. DOI: 10.1002/ece3.8504.

Gurumayum SD. 2019. On a collection of some Mollusca from Budhabalanga Estuary, Odisha. Rec Zool Surv India 119 (1): 55-59.

Hafiz Md, Sajan SK, Mukhopadhyay A, Tripathy B, 2021. *Mactra aequisulcata* G. B. Sowerby III 1894 in India (Mollusca: Bivalvia: Mactridae)-A review on the past and present new distribution of an ambiguous clam. Thalassas: Intl J Mar Sci 37: 577-583. DOI: 10.1007/s41208-021-00311-6.

Herawati H, Patria E, Hamdani H, Rizal A. 2020. Macrozoobenthos diversity as a bioindicator for the pollution status of Citarik River, West Java. IOP Conf Ser: Earth Environ Sci 535 (1): 012008. DOI: 10.1088/1755-1315/535/1/012008.

Hidayah N, Ambarwati R. 2020. Diversity and abundant of bivalves in the intertidal zone of Boom Beach, Tuban. LenteraBio 9 (2): 90-98. DOI: 10.26740/lenterabio.v9n2.p90-98. [Indonesian]

Holtappels M, Glud RN, Donis D, Liu B, Hume A, Wenzhöfer F, Kuypers MMM. 2013. Effects of transient bottom water currents and oxygen concentrations on benthic exchange rates as assessed by eddy correlation measurements. J Geophys Res: Oceans 118 (3): 1157-1169. DOI: 10.1002/jgrc.20112.

Huber M. 2010. Compendium of Bivalves. ConchBooks, Hackenheim, Germany.

Irham M, Ihsan M, Octavina C. 2017. Study of Benthic Abundance And Diversity In Krueng Cut Estuary, Banda Aceh. Proceedings of the 7th AIC-ICMR on Health and Life Sciences. Syiah Kuala University, October 18-20, 2017, Banda Aceh, Indonesia.

Irham M, Ihsan M, Oktavina C, Sugianto S, Nur FM, Batubara AS. 2020. The abundance and diversity of benthic community in Krueng Cut Estuary, Banda Aceh, Indonesia. Biharean Biol 14 (2): 85-89.

Jost J. 2017. Relations and dependencies between morphological characters. Theory Biosci 136 (1-2): 69-83. DOI: 10.1007/s12064-017-0248-z.

Lamprell K Whitehead T. 1992. Bivalves of Australia. Volume 1. Crawford House Press, Bathurst, New South Wales, Australia.

Lase Y, Taib EN, Ahadi R. 2021. Class species of gastropods and bivalvia in Muara Saragian, Aceh Singkil District. Pros Sem Nas Biotik 9 (1): 115-120. DOI: 10.22373/pbio.v9i1.11559. [Indonesian]

Minister of Environment Decree. 2004. Sea Water Quality Standards (51). [Indonesian]

MolluscaBase eds. 2022. MolluscaBase. *Mactra* Linnaeus, 1767. World Register of Marine Species. https://www.marinespecies.org/aphia.php?p=taxdetails&id=138158 on 2022-12-26

Octavina C, Dewiyanti I, Nurfadillah N, Ulfah M, Razi NM, Sakinah R, Agustiar, M. 2019. Community structure of macrozoobenthos in Lamnyong River, Aceh Province. IOP Conf Ser: Earth Environ Sci 348 (1): 012070. DOI: 10.1088/1755-1315/348/1/012070.

Poutiers JM. 1998. Bivalves (Acephala, Lamellibranchia, Pelecypoda). In: Carpenter KE, Niem VH (eds). FAO Species Identification Guide for Fishery Purposes; The Living Marine Resources of the Western Central Pacific Volume 1. FAO, Rome.

Ramakrishna DA. 2010. Annotated checklist of Indian Marine Molluscs (Cephalopoda, Bivalvia and Scaphopoda): Part 1. Records of Zoological Survey of India. Occasional Paper, Kolkata.

Rao NVS. 2017. Indian Seashells (Part II), Bivalvia. Records of Zoological Survey of India. Occasional Paper, Kolkata.

Robin A. 2011. Encyclopedia of Marine Bivalves, Including Scaphopod, Polyplacophora dan Cephalopods. Conchbooks, Germany.

Signorelli JH, Márquez F, Pastorino G. 2013. Phenotypic variation of south-western Atlantic clam *Mactra isabelleana* (Bivalvia: Mactridae). J Mar Biol Assoc United Kingdom 93 (2): 511-517. DOI: 10.1017/S0025315412000410.

Suhanda D, Yuniarti MS, Nurul Ihsan Y, Harahap SA. 2019. Nutrient Concentration and population of macrozoobenthos in Ciletuh Bay, Sukabumi District, West Java. IOP Conf Ser: Earth Environ Sci 406 (1): 012014. DOI: 10.1088/1755-1315/406/1/012014.

Tudu CP, Ray D, Mohapatra A. 2017. An account of Molluscan fauna of Digha Coast, Bay of Bengal. National Seminar on Role of Biodiversity and Natural Resources in Sustainable Development. Bajkul Milani Mahavidyalaya, February 2017.

Vieira AR, Rodrigues ASB, Sequeira V, Neves A, Paiva RB, Paulo OS, Gordo LS. 2016. Genetic and morphological variation of the forkbeard, *Phycis phycis* (Pisces, Phycidae): Evidence of panmixia and recent population expansion along its distribution area. PLoS ONE 11 (12): 1-19. DOI: 10.1371/journal.pone.0167045.

Wong HW. 2009. The Mactridae (Mollusca: Bivalvia) of East Coast Park, Singapore. Nat Singapore 2: 283-296.

Zhang C, Xue S, Li J, Fang J, Liu L, Ma Z, Yu W, Zhuang H, Mao Y. 2022. Influences of substrate grain size on the burrowing behavior of juvenile *Meretrix meretrix*. Animals 12 (16): 1-16. DOI: 10.3390/ani12162094.