Jurnal Riset Biologi dan Aplikasinya
https://journal.unesa.ac.id/index.php/risetbiologi

Morphological and Morphometric Study of *Pila celebensis* (Gastropoda: Ampullariidae) from Madura Island, Indonesia

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Article History

Received : 4 September 2025
Revised : 18 September 2025
Accepted : 29 September 2025
Published : 31 September 2025

Keywords
Ampullariidae; Freshwater snails; Habitat; Shell characteristics

ABSTRACT

Pila celebensis (family Ampullariidae) is a native freshwater snail species found in Asia, including Indonesia, and possesses significant ecological and economic importance. However, *Pila* populations face various threats due to the invasiveness of *Pomacea*, as well as human activities. This study aimed to document the presence of *P. celebensis* on Madura Island and describe its morphological and morphometric characteristics. Samples were collected from four localities in Madura. All specimens had a similar morphological shell, including a spherical shell with a prominent brown color and dark brown spiral pattern, an oval to elongate lunar aperture, a thin or closed umbilicus, and a concentric operculum. However, morphometric size varied significantly by location. The largest individuals were found in the rice fields of South Poter Village, while the smallest were found in a stream in Nyalabuh Laok Village. This difference reveals that environmental factors, notably habitat conditions and food quality, have a significant impact on shell growth, with higher nutrition supporting larger sizes.

How to cite: Hanuninda, D., Ambarwati, R., Isnaningsih, N.R. (2025). Morphological and Morphometric Study of *Pila celebensis* (Gastropoda: Ampullariidae) from Madura Island, Indonesia. *Jurnal Riset Biologi dan Aplikasinya*, 7 (2): 160-167. DOI: 10.26740/jrba.v7n2.p.160-167.

INTRODUCTION

The family Ampullariidae is a group of freshwater snails that consists of 9 genera, which are: *Afropomus* Pilsbry & Bequaert, 1927, *Forbesopomus* Bequaert & Clench, 1937, *Lanistes* Montfort, 1810, *Pila* Roding, 1798, *Saulea* Gray, 1868, *Asolene* A. d'Orbigny, 1838, *Felipponea* Dall, 1919, *Marisa* J. E. Gray, 1824, and *Pomacea* Perry, 1810 (MolluscaBase, 2024). Previous studies have recorded more than 150 species in the family Ampullariidae, showing a very high level of diversity (Hayes et al., 2009). This family is even considered one of the largest groups of freshwater snails in the world (Ng et al., 2020; Thaewnon-ngiw et al., 2003). The most prevalent genera within this family are *Pomacea* and *Pila* (MolluscaBase, 2024). *Pomacea* is known for its very wide distribution. The species of *Pomacea canaliculata*, is known as a major pest in rice farmland because it damages crops and disrupts the balance of freshwater ecosystems (Bae et al., 2021; Luo et al., 2023; Md Latip & Clement, 2021). The Ampullariidae species have a high ability to adapt and are able to survive in various environments (Hayes et al., 2015; Ip et al., 2018; Jabal et al., 2022). Due to their estivation ability, Ampullariidae can survive in a dry environment for a relatively long time (Hayes et al., 2015; Marwoto & Isnaningsih, 2014). Members of the family Ampullariidae demonstrate a high degree of resilience to chemical contaminants originating from agricultural practices. The intensive use of synthetic chemicals in conventional farming reduces macroinvertebrate diversity and stability, whereas organic farming methods better conserve these ecological community attributes (Kurnianto et al., 2022). One of the unique features of Ampullariidae

is the way they reproduce; they lay eggs above the surface of the water to protect the embryo from aquatic predators (Djeddour et al., 2021; Ip et al., 2018; Luo et al., 2023).

The genus *Pila* has around 30 species that are widely distributed in tropical and subtropical regions. The main distribution of this genus is in Asia and Africa (Hayes et al., 2015; Panda et al., 2022). The genus *Pila* is believed to have originated in Africa and then migrated to Asia, possibly due to continental drift (Panda et al., 2022; Sil et al., 2020). One species of *Pila* known to exist in Indonesia is *Pila celebensis*. Large-shelled *Pila* specimens conforming to the descriptions of Djajasasmita (1987), Marwoto et al. (2011), Ng et al. (2014), and Ng et al. (2019) were classified as *Pila ampullacea* for a long time. Based on geometric morphometric analysis and molecular evidence, Ng et al. (2020) reexamined the identity and taxonomy of *Pila ampullacea* from Southern Thailand, together with specimens from outside Southern Thailand, the Malay Peninsula, and the Greater Sunda Islands, and determined them as *Pila celebensis*.

Pila celebensis, plays an important role in ecosystems. Their feeding activity, which targets algae, senescent plant material, and organic detritus, provides ecosystem services related to water purification. Therefore, this species contributes to reducing aquatic vegetation that often clogs waterways, and also helps to manage aquatic weeds (Patel & Kurhe, 2023). *Pila celebensis* is also used as an alternative source of protein, which is processed into various types of food, such as baby porridge, various liquid foods, crackers, and food flavor enhancers (Broto et al., 2020; Fatimah et al., 2018; Ihsani et al., 2020; Rompas et al., 2023). From the field of aquaculture and fisheries perspective, *P. celebensis* and *P. globosa* have an important role, providing livelihoods and income sources for communities reliant on these snails (Jadhav et al., 2023; Kasim et al., 2023). The mucus of *P. celebensis* is known to contain vitamin C, which is beneficial for the health of the body and skin. In addition, it also has pharmacological properties, including anti-microbial, antioxidant, and antitumor, and contains other active compounds that promote burn wound healing (Septiani et al., 2023).

Some species of *Pila* are categorized as Least Concern by the International Union for Conservation of Nature (IUCN), meaning that these species still face various types of threats to their lives from human activities. For example, changes in habitat due to urbanization and land conversion for agriculture have reduced their natural habitat, causing fragmentation that disrupts their reproductive patterns. In addition, water pollution from various industrial and agricultural waste also affects the habitat quality of *Pila* and disrupts *Pila's* health and reproduction (Marwoto et al., 2020b).

Pila celebensis is considered a pest species for plants, especially in rice plants (Rompas et al., 2023). However, the pesticidal impact of *Pila celebensis* is less significant than that of *Pomacea canaliculata*. Molluscicides applied for *P. canaliculata* are non-selective, consequently impacting the non-target species, *P. celebensis*, which shares the same ecological niche (Martín et al., 2019).

According to Djajasasmita (1987), *P. celebensis* in Indonesia is one of the largest freshwater snails in size. The shell can grow up to 100 mm and has a diameter of ± 100 mm. *Pila celebensis* can be found in almost all regions in Indonesia, especially in areas with fresh water that is not very fast. The areas in Indonesia that are the main homes of these snails are Kalimantan, Sumatra, Java, and Sulawesi. *Pila celebensis* is generally found in shallow water areas such as freshwater waters, lakes, ponds, or various streams of water that have a moderate flow (Suartini & Sudatri, 2022). The results of research conducted by Normasitah et al. (2023), on the morphology of the *P. celebensis* rice field snail in the Pontianak City, rice field area, show that this species has a black to blackish green shell with a rounded conical shape.

Madura Island is one of the islands in East Java that remains the habitat of Ampullariidae. Madura is located in the northeast of Java Island, covering four administrative areas consisting of four districts, namely: Bangkalan Regency, Sampang Regency, Pamekasan Regency, and Sumenep Regency (Rahman, 2018). Madura Island is located at a latitude of about 7° south and between 112° and 114° east longitude. The length of Madura Island is about 190 km, with the widest distance of around 40 km. The total area is 5,304 km². levation ranges from 2 to 350 m above sea level, with the lowest altitude being the coastal areas in the east, west, south, and north of the island (Razy & Mahzuni, 2021).The purpose of this study is to document the presence of *P. celebensis* on Madura Island and describe the morphological and morphometric characteristics.

MATERIALS AND METHODS

Sample Collection

Sampling were carried out from March to December 2024 in the following localities: (1) River of Bangkalan Regency (7°09'42.4"S 112°53'04.0"E), (2) Rice Field of South Poter Village, Tanah Merah Subdistrict, Bangkalan Regency (7°04'07.1"S 112°49'42.3"E), (3) River of Nyalabuh Laok Village, Pamekasan Regency (7°08'53.0"S 113°27'51.0"E), (4) Rice Fields of Torjun Village, Keddeng Hamlet, Sampang Regency (7°09'20.0"S 113°11'07.6"E) (Figure 1). All collected specimens were stored in the Taxonomy Laboratory, Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya.

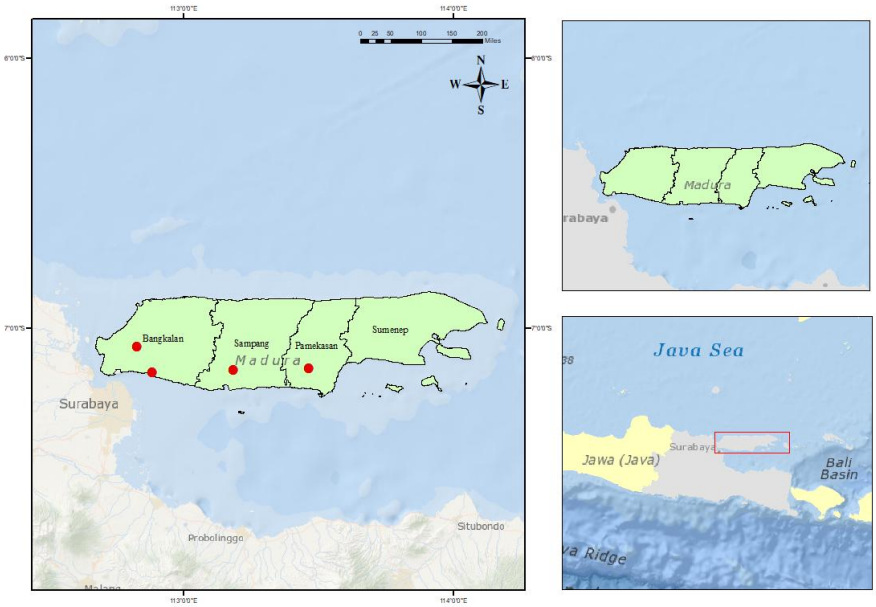

Figure 1. Sampling localities of *P. celebensis* on Madura Island, Indonesia

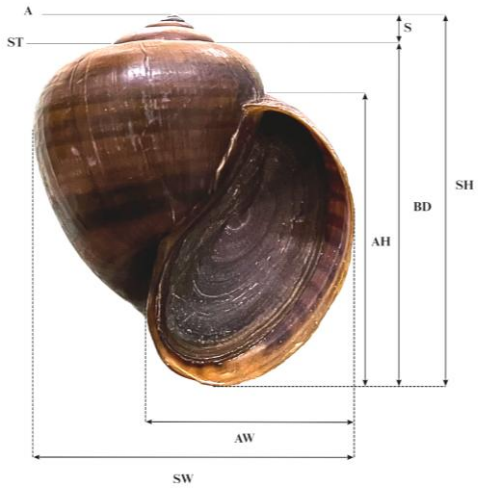

Figure 2. The parts of a *Pila celebensis* shell and their measurement dimensions : apex (A), suture (ST), shell height (SH), shell width (SW), spire (S), body whorl (BD), aperture width (AW) and aperture height (AH)

Species Identification and Morphometric Measurements

Morphometric measurements included shell height (SH), shell width (SW), spire (S), body whorl (BD), aperture width (AW), and aperture height (AH), which were measured using a vernier caliper (Figure 2). The observed characteristics were shell shape, shell color, shell pattern, shell surface ornamentation, which includes axial and spiral growth lines, as well as operculum shape. Species identification was performed based on the characteristics or morphology of shells following Dharma (2005), and taxonomic was carried out using *MolluscaBase*.

Data analysis

The morphometric data were analyzed with PAST 4.04 software using the Principal Component Analysis (PCA) method as a way to identify patterns and groupings among specimens based on morphometrics. PCA generated eigenvalues indicating the contribution of each component to the total variance.

RESULTS AND DISSCUSION

Nineteen individuals of *P. celebensis* were obtained from field sampling. The following section provides details about the systematics and description of *P. celebensis* species.

Systematics

Kingdom Animalia
Phylum Mollusca
Class Gastropoda
Order Architaenioglossa
Family Ampullariidae
Genus *Pila*
Species *Pila celebensis* (Quoy & Gaimard, 1834) (Fig. 3; Fig. 4)
Pila ampullacea – Komalamisra et al., 2009: 245, Figure 1-A
Pila ampullacea – Ng et al., 2014: 33, Figure 2
Pila ampullacea – Ng et al., 2019: 5, Figure 2-A
Pila ampullacea – Marwoto et al., 2020a: 2, Figure 1-A
Pila celebensis – Ng et al., 2020: 298, Figure 7-A

Material examined

LTH.GST.170B, River Flow of Bangkalan Regency (7°09'42.4"S 112°53'04.0"E), n: 8; LTH.GST.170A Rice Field of South Poter Village, Tanah Merah Subdistrict, Bangkalan Regency (7°04'07.1"S 112°49'42.3"E), n: 5; LTH.GST.170C, River Flow of Nyalabuh Laok Village, Pamekasan Regency (7°08'53.0"S 113°27'51.0"E), n: 3. LTH.GST.170D, Rice fields of Torjun Village, Keddeng Hamlet, Sampang Regency (7°09'20.0"S 113°11'07.6"E), n: 3.

Diagnosis

The shell of *P. celebensis* is characterized by a globose shell, with transverse lines, apex is not very prominent, the spire is low, spire terraced, the aperture is elongate, lunar, and the umbilicus is narrow.

Description

Morphology - Shell: Large (shell height about 17-72.25 mm, shell width 14.75-70 mm), globose, thick, and dense. Color dark brown to yellowish brown. The shell coils in a dextral direction with about 4-5 whorls. The surface is plain and smooth with a soft lustre, striated with transverse lines. The spire is elevated; the suture is shallow and without a channel. The umbilicus is narrow or closed. The Aperture is oval to elongate lunar or oblique, slightly widened at the base. Operculum: solid and calcified, oval to elongate lunar, concentric with a subcentral nucleus, and flat on its external surface.

Principal Component Analysis

The eigenvalue is a comparison value on the Principal Component that can be used in grouping data. Principal Component 1 is the main axis that shows the maximum value in data variability. Meanwhile, Principal Component 2 is an axis that shows the minimum value in variability that is not taken into account in Principal Component 1, so the use of Principal Component 1 in describing data is important (Ma et al., 2011).

The largest eigenvalue is associated with PC1, which is 1125.69, explaining 98.67% of the total variance. Meanwhile, PC2 has an eigenvalue of 6.98, accounting for 0.61% of the total variance. Thus, further analysis can use Principal Component 1 and Principal Component 2 as a comparison. The eigenvalues on Principal Components 3 to 6 are very small, so it can be ignored. Based on the eigenvalues of Principal Component 1 and Principal Component 2, there are quadrants 1 to quadrant 4. It is known that the parameters of the body whorl (BD), shell height (SH), and spire (S) occupy Quadrant 1 or are located between the positive X and positive Y axes which have a strong correlation on the differences of the four locations. As for the parameters of shell width (SW), aperture height (AH), and aperture width (AW), they are in Quadrant 4, located between the positive X and negative Y axes, indicating that these parameters are weakly correlated with the differences of the four *P. celebensis* species locations.

The distribution of morphometric data on the scatter plot shows that there are four different groups. Three individuals of *P. celebensis* species found in Poter Village are located in Quadrant 1 and 2 individuals are located in Quadrant 4, where 3 individuals of *P. celebensis* species located in quadrant 1 have a strong correlation with the parameters of body whorl (BD), shell height (SH), and spire (S), while 2 individuals in Quadrant 4 have a weak correlation with the parameters of shell width (SW), aperture height (AH), and aperture width (AW). All individuals of *P. celebensis* species

found in the rice fields of Torjun Village are located in Quadrant 2 (Figure 4), which has a weak correlation with the parameters of body whorl (BD), shell height (SH), and spire (S). On the other hand, in individuals of *P. celebensis* species found in Bangkalan River and Nyalabuh Laok River, most of them are located in Quadrant 3, which also shows a weak correlation, indicating that the shell size decreases with distance from the parameter point. Some other individuals are in Quadrant 2, similarly exhibiting a weak correlation with the parameters of body whorl (BD), shell height (SH), and spire (S).

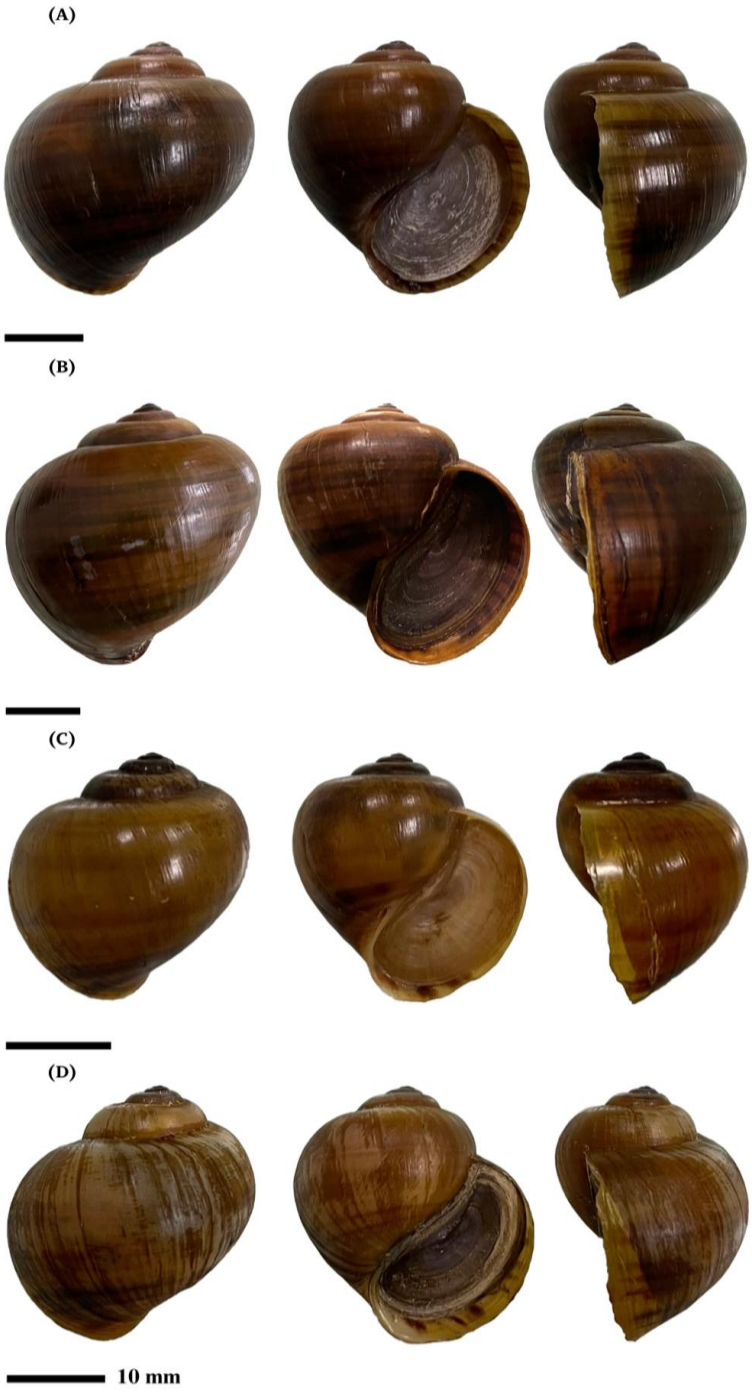

Figure 3. *Pila celebensis* from Madura Island: A) River Flow of Bangkalan Regency, B) Rice Field of South Poter Village, Tanah Merah Subdistrict, Bangkalan Regency, C) River Flow of Nyalabuh Laok Village, Pamekasan Regency, D) Rice fields of Torjun Village, Keddeng Hamlet, Sampang Regency

Table 1. Eigenvalues of shell morphometry data of *P. celebensis* species

PC	Eigenvalue	% variance
1.	1125.69	98.668
2	6.9841	0.61216
3	5.61695	0.49233
4	1.51082	0.13242
5	0.871432	0.076382
6	0.212795	0.018652

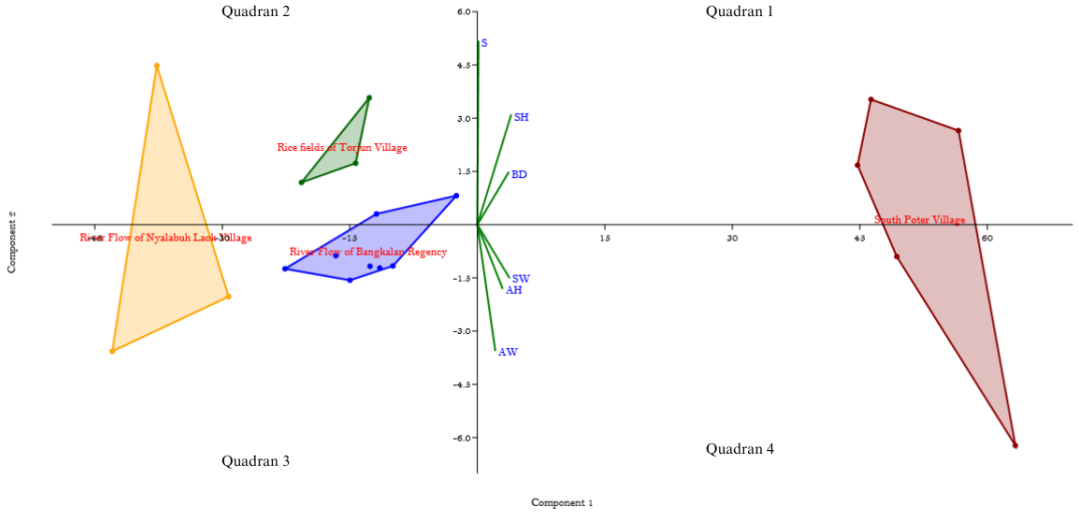

Figure 4. Scatter plot of *P. celebensis* shell morphometry data from four sites using Principal Component Analysis (PCA)

Shell Morphological Characteristics

The shell morphology of the observed *P. celebensis* specimens is consistent with descriptions by Ng et al. (2020) and Marwoto et al. (2020a), characterized by a globose shape. The dominant shell color is brown with striated transverse lines. The spire is elevated, and the suture is shallow without a channel (Figure 3). Umbilicus is narrow or closed. The Aperture oval to elongate lunar or oblique. Furthermore, the research conducted by Ng et al. (2014) reported that *P. celebensis* has a smooth shell surface with fine axial lines. In some individuals, brown spiral lines of varying thickness are visible inside the aperture. Axial brown lines marking previous growth stages are present, and the inner lip of the aperture is typically yellow to light orange. These findings are consistent with the present study.

Shell Size Variation Among Habitats

Variation in shell size among *P. celebensis* populations from different sampling sites reflects the influence of habitat differences. Snails inhabiting environments with high organic content, such as rice fields, generally exhibit larger shells compared to those from river habitats (Cazzaniga, 2006; Isnaningsih & Marwoto, 2011; Suarmustika et al., 2018). The present results are consistent with this pattern, as the largest *Pila* was collected from rice fields of South Poter Village, while the smallest was collected from the river flow of Nyalabuh Laok Village. Previous studies have also suggested that shell size may be influenced by food availability and predation pressure. Based on studies conducted by Kumaladewi (2009), there is a positive relationship between shell size and consumption level, with large snails have the highest ability to consume food. Although the current study did not explicitly

measure food resources, the previously established findings provide possible explanations for the observed shell size variation in *P. celebensis*.

CONCLUSION

This study identified the morphological and morphometric characteristics of *P. celebensis* distributed on Madura Island. The morphological characteristics of the shell of *P. celebensis* is characterized by a globose shape with a smooth surface and fine axial lines. The dominant shell color is brown with striated transverse lines. Shell spire elevated. Suture shallow without any channel. Umbilicus is narrow or closed. The Aperture oval to elongate lunar or oblique. In some individuals, brown spiral lines of varying thickness are visible inside the aperture. The axial brown lines marking previous stages of growth rest, and the inner lips of the aperture are usually yellow or light orange. Meanwhile, morphometric measurement characteristics show variations in shell size. *P. celebensis*, the largest shell size, is found in the rice fields of South Poter Village. Meanwhile, *P. celebensis*, which has the smallest size, was found on the river flow Nyalabuh Laok Village. These results confirm that environmental factors, such as habitat conditions and food source availability, play an important role in the morphometric variation of *P. celebensis*.

ACKNOWLEDGMENTS

This publication is one of the results of the "MBKM Research/Research 2024" program; therefore, we thank the MBKM Team and LPPM, Universitas Negeri Surabaya, Surabaya, Indonesia.

REFERENCES

Bae, M. J., Kim, E. J., & Park, Y. S. (2021). Comparison of invasive apple snail (Pomacea canaliculata) behaviors in different water temperature gradients. *Water (Switzerland)*, *13*(9). https://doi.org/10.3390/w13091149

Broto, R. T. D. W., Arifan, F., Setyati, W. A., Eldiarosa, K., & Zein, A. R. (2020). Crackers from Fresh Water Snail (Pila ampullacea) Waste as Alternative Nutritious Food. *IOP Conference Series: Earth and Environmental Science*, *448*(1). https://doi.org/10.1088/1755-1315/448/1/012039

Cazzaniga, N. J. (2006). *Pomacea canaliculata*: Harmless and useless in its natural realm (Argentina). In R. C. Joshi & L. S. Sebastian (Eds.), *Global advances in ecology and management of golden apple snails* (pp. 37–60). PhilRice.

Dharma, B. (2005). *Recent and Fossil Indonesian Shells*. Conchbooks.

Djajasasmita, M. (1987). Keong Gondang Pila ampullacea Makanan dan Reproduksinya (Gastropoda : Ampullaritoae), *Berita Biologi*, *3*(7), 342–346.

Djeddour, D., Pratt, C., Makale, F., Rwomushana, I., & Day, R. (2021). The apple snail, Pomacea canaliculata: an evidence note on invasiveness and potential economic impacts for East Africa. In *CABI Working Paper* (Issue 21). https://doi.org/10.1079/CABICOMM-62-8149

Fatimah, I., Aulia, G. R., Puspitasari, W., Nurillahi, R., Sopia, L., & Herianto, R. (2018). Microwave-synthesized hydroxyapatite from paddy field snail (Pila ampullacea) shell for adsorption of bichromate ion. *Sustainable Environment Research*, *28*(6), 462–471. https://doi.org/10.1016/j.serj.2018.10.003

Hayes, K. A., Cowie, R. H., & Thiengo, S. C. (2009). A global phylogeny of apple snails: Gondwanan origin, generic relationships, and the influence of outgroup choice (Caenogastropoda: Ampullariidae). *Biological Journal of the Linnean Society*, *98*(1), 61–76. https://doi.org/10.1111/j.1095-8312.2009.01246.x

Hayes, K. A., Burks, R. L., Castro-Vazquez, A., Darby, P. C., Heras, H., Martín, P. R., Qiu, J. W., Thiengo, S. C., Vega, I. A., Wada, T., Yusa, Y., Burela, S., Cadierno, M. P., Cueto, J. A., Dellagnola, F. A., Dreon, M. S., Frassa, M. V., Giraud-Billoud, M., Godoy, M. S., … Cowie, R. H. (2015). Insights from an integrated view of the biology of apple snails (caenogastropoda: Ampullariidae). *Malacologia*, *58*(1–2), 245–302. https://doi.org/10.4002/040.058.0209

Ihsani, K., Afifah, D. N., Anantyo, D. T., Mulyono, Nugroho, T. W., Wahyudi, F., & Nuryanto. (2020). Nutrient content and shelf life analysis of freshwater snail (Pila ampullacea) instant baby porridge. *Food Research*, *4*(S3), 184–196. https://doi.org/10.26656/fr.2017.4(s3).s20

Ip, J. C. H., Mu, H., Chen, Q., Sun, J., Ituarte, S., Heras, H., Van Bocxlaer, B., Ganmanee, M., Huang, X., & Qiu, J. W. (2018). AmpuBase: A transcriptome database for eight species of apple snails (Gastropoda: Ampullariidae). *BMC Genomics*, *19*(1), 1–10. https://doi.org/10.1186/s12864-018-4553-9

Isnaningsih, N. R., & M Marwoto, R. (2011). Keong hama Pomacea di Indonesia: karakter morfologi dan sebarannya(Mollusca, Gastropoda: Ampullariidae). *Berita Biologi*, *10*(4), 441–447. https://e-journal.biologi.lipi.go.id/index.php/berita_biologi/article/view/761

Jabal, A. R., Akbar, H., Setyaji, F. A. D., Riyadi, N. R., Balyas, A. B., Putra, I. P., Toemon, A. I., & Ratnasari, A. (2022). Freshwater Snail as Intermediate Host of Trematode in Water Channels of Palangka Raya City. *Al-Kauniyah: Jurnal Biologi*, *15*(1), 164–170. https://doi.org/10.15408/kauniyah.v15i1.25957

Jadhav, A., Das, N. K., Sil, M., & Aravind, N. A. (2023). Snails on the plate: Edible freshwater molluscs of Northeast India. *Indian Journal of Traditional Knowledge*, *22*(2), 409–419. https://doi.org/10.56042/ijtk.v22i2.55225

Kasim, S., Hala, Y., & Sri Rahayu, L. (2023). Application of Rice Field Snails (Pila ampullacea) Extract as an Alternative Substitute for Protein Sources in Export-Quality Catfish Feed (Clarias sp.). *Indo. J. Chem. Res.*, *11*(2), 118–127. https://doi.org/10.30598/ijcr.2023.11-sya

Komalamisra, C., Nuamtanong, S., & Dekumyoy, P. (2009). Pila Ampullacea and Pomacea Canaliculata, as new paratenic hosts of Gnathostoma spinigerum. *Southeast Asian Journal of Tropical Medicine and Public Health*, *40*(2), 243–246.

Kumaladewi, P. (2009). *Tingkat konsumsi pada dua populasi keong murbei (Pomacea canaliculata) sebagai alternatif penanganan gulma air* [Undergraduate thesis, Institut

Pertanian Bogor]. IPB Repository. https://repository.ipb.ac.id/handle/123456789/12985

Kurnianto, A. S., Purnomo, H., & Septiadi, L. (2022). The Influence of Agrochemicals on Macroinvertebrate Community Structure in Various Agricultural Rivers in Jember Regency. *Journal of Tropical Biodiversity and Biotechnology*, *7*(1), 1–15. https://doi.org/10.22146/jtbb.69425

Luo, D., Li, Y., & Li, J. (2023). Concerns on research history overview, distribution patterns, and potentially neglected ecological consequences of the invasive apple snail (*Pomacea* sp.): A review. *BioRxiv*. Advance online publication. http://biorxiv.org/content/early/2023/12/24/2023.12.23.573227

Ma, Y., Gomez, E., Luneau, B., Iwere, F., Young, T. J., & Cox, D. L. (2011). Integrated reservoir modeling of a pinedale tight-gas reservoir in the Greater Green River Basin, Wyoming. *AAPG Memoir*, *96*, 89–106. https://doi.org/10.1306/13301409M963458

Martín, P. R., Burela, S., Seuffert, M. E., Tamburi, N. E., & Saveanu, L. (2019). Invasive Pomacea snails: Actual and potential environmental impacts and their underlying mechanisms. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*, *14*(042). https://doi.org/10.1079/PAVSNNR201914042

Marwoto, R. M., Isnaningsih, N. R., Mujiono, N., Heryanto, Alfiah, & Riena. (2011). *Keong air tawar Pulau Jawa (Moluska, Gastropoda)*. Pusat Penelitian Biologi, Lembaga Ilmu Pengetahuan Indonesia.

Marwoto, R. M., Heryanto, H., & Joshi, R. C. (2020a). The invasive apple snail Pomacea canaliculata in Indonesia: a case study in Lake Rawa Pening, Central Java. *BIO Web of Conferences*, *19*, 19–23. https://doi.org/10.1051/bioconf/20201900014

Marwoto, R. M., Heryanto, Isnaningsih, N., Mujiono, N., Alfiah, & Prihandini, R. (2020b). *Moluska Jawa (Gastropoda & Bivalvia)* (Issue May). LIPI Press

Marwoto, R. M., & Isnaningsih, N. R. (2014). Tinjauan Keanekaragaman Moluska Air Tawar di Beberapa Situ di DAS Ciliwung - Cisadane. *Berita Biologi*, *13*(2), 181–189.

Md Latip, S. N. H., & Clement, M. U. (2021). The effects of different water temperatures on survival and growth rate of juvenile invasive apple snail, Pomacea canaliculata (Lamarck, 1822) under controlled environment. *IOP Conference Series: Earth and Environmental Science*, *685*(1). https://doi.org/10.1088/1755-1315/685/1/012021

MolluscaBase Eds. (2024). *MolluscaBase. Ampullariidae J. E. Gray, 1824. Accessed at: https://www.molluscabase.org/aphia.php?p=taxdetails&id=549357 on 2024-10-21.*

Ng, T. H., Low, M., & Tan, S. K. (2014). Singapore Mollusca: 7. The family Ampullariidae (Gastropoda: Caenogastropoda: Ampullarioidea). *Nature in Singapore*, 31-47.

Ng, T. H., Tan, S. K., Ahmad, A., Van Tu, D., Joshi, R. C., Wang, W. Y., Tan, H. H., & Yeo, D. C. J. (2019). Not in the Least Concern: Anthropogenic influences on a South-east Asian apple snail Pila scutata (Ampullariidae). *Oryx*, *53*(2), 230–238. https://doi.org/10.1017/S0030605318000443

Ng, T. H., Annate, S., Jeratthitikul, E., Sutcharit, C., Limpanont, Y., & Panha, S. (2020). Disappearing apple snails (Caenogastropoda: Ampullariidae) of Thailand: A comprehensive update of their taxonomic status and distribution. *Journal of Molluscan Studies*, *86*(4), 290–305. https://doi.org/10.1093/mollus/eyaa015

Normasitah, S., Rousdy, D. W., & Setyawati, T. R. (2023). Morfologi Keong Sawah (Pila ampullacea Linnaeus, 1758) yang Terpapar Logam Berat di Area Perswahan. *Jurnal Protobiont*, *12*(3), 73–76.

Panda, F., Pati, S. G., Das, K., Samanta, L., Sahoo, D. K., & Paital, B. (2022). Biochemical and molecular responses of the freshwater snail Pila sp. to environmental pollutants, abiotic, and biotic stressors. *Frontiers in Environmental Science*, *10*(November), 1–19. https://doi.org/10.3389/fenvs.2022.1033049

Patel, R. J., & Kurhe, A. R. (2023). Freshwater shellfish, Pila globosa: a review on its ecological and economical importance, nutritive and ethno-medicinal values. *Environmental and Experimental Biology*, *21*(2), 61–66. https://doi.org/10.22364/eeb.21.08

Rahman, A. (2018). Aplikasi Mad Ento "Madura Explore and Tour" dengan penerapan metode Location Based Service (LBS) berbasis Android. *Jurnal Mahasiswa Teknik Informatika*, *2*(1), 84–91.

Razy, M. R. O. A., & Mahzuni, D. (2021). Sosial Ekonomi Masyarakat Madura Abad 19-20: Sebuah Kajian Ekologi Sejarah. *Jurnal Siginjai*, *1*(2), 65–79. https://doi.org/10.22437/js.v1i2.16241

Rompas, J. J. I., Laatung, S., Gunawan, W. Ben, Widayanti, I. S., Yusuf, V. M., Yusuf, T. W., Salindeho, N., Samtiya, M., & Nurkolis, F. (2023). Rice field snail shell anticancer properties: An exploration opinion. *Frontiers in Oncology*, *12*(January), 1–5. https://doi.org/10.3389/fonc.2022.1078981

Septiani, N. I., Yuniarti, E., Helendra, H., & Atifah, Y. (2023). Analysis of Vitamine C Levels in Rice Snail Mucus (Pila ampullacea). *Jurnal Biologi Tropis*, *23*(3), 189–193. https://doi.org/10.29303/jbt.v23i3.4995

Sil, M., Aravind, N. A., & Karanth, K. P. (2020). Into-India or out-of-India? Historical biogeography of the freshwater gastropod genus Pila (Caenogastropoda: Ampullariidae). *Biological Journal of the Linnean Society*, *129*(3), 752–764. https://doi.org/10.1093/biolinnean/blz171

Suarmustika, I. G. A., Suartini, N. M., & Subagio, J. N. (2018). Variasi Morfometri dan Karakter Morfologi Keong Mas (Pomacea canaliculata) Pada Sawah di Desa Abiansemal Badung-Bali. *Simbiosis*, *6*(2), 60. https://doi.org/10.24843/jsimbiosis.2018.v06.i02.p06

Suartini, N. M., & Sudatri, N. W. (2022). Density, Morphology and Egg Clusters of Pila scutata Snails at Rice Fields Area in Peringsari Village, Bali. *KnE Life Sciences*, *2022*, 435–443. https://doi.org/10.18502/kls.v7i3.11150

Thaewnon-ngiw, B., Lauhachinda, N., Sri-Aroon, P., & Lohachit, C. (2003). Distribution of Pila polita in a southern province of Thailand. *The Southeast Asian Journal of Tropical Medicine and Public Health*, *34 Suppl 2*(Suppl 2), 128–130.