

Freshwater Snails Diversity and Distribution in the Kaduara Sulfurous Spring, Sumenep, Madura, Indonesia

Fara Salsa Refalina Sidarta¹, Reni Ambarwati^{2*}, Nur Rohmatin Isnainingsih³

¹Biology Study Program, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, Unesa Campus 1, Ketintang, Surabaya 60231, East Java, Indonesia

²Department of Aquaculture, Faculty of Food Security, Universitas Negeri Surabaya. Unesa Campus 3, Jl. Prof. Dr. Moestopo No. 4, Surabaya 60286, East Java, Indonesia

³Research Center for Biosystematics and Evolution, BRIN. Jln. Raya Jakarta-Bogor Km. 46, Cibinong, Bogor, West Java, Indonesia, 16911

*Corresponding author, e-mail: reniambarwati@unesa.ac.id

ARTICLE HISTORY

Received: 10 January 2026

Revised :12 February 2026

Accepted: 25 March 2026

Published Online: 31 March 2026

Keywords:

Sulfurous spring;

Gastropods;

Thiaridae;

Neritidae;

Shell size

This is an open-access article under the CC BY-NC licence

<https://creativecommons.org/licenses/by-nc/4.0/>

e-ISSN [2655-9927](https://doi.org/10.26740/jrba.v8n1.p18-33)

ABSTRACT

Sulfurous spring habitats represent chemically extreme aquatic environments that typically support limited freshwater biodiversity; however, the gastropod fauna of such habitats in tropical Indonesia remains largely undocumented. This study aimed to document the diversity, morphology, morphometry, and physicochemical associations of freshwater gastropods inhabiting the Kaduara Sulfurous Spring, Sumenep, Madura Island, Indonesia. Specimens were collected on 17 July 2024 using the hand-picking method at one sampling point (coordinates: -7.1237°S, 113.6062°E), preserved in 70% alcohol. Physicochemical parameters were measured in situ, and sulfur content was determined gravimetrically following SNI 02-1760-2005. A total of seven freshwater gastropod species from two families were recorded: *Stenomelania rustica*, *Stenomelania torulosa*, *Stenomelania* sp., *Mieniplotia scabra*, and *Melanoides tuberculata* (Thiaridae), along with *Neritina cornuta* and *Clithon* sp. (Neritidae). The spring exhibited a water temperature of 29°C, pH of 7, and total sulfur content of 0.077% (770 mg/L). Shell dimensions of all recorded species were consistent with published reference ranges, indicating normal growth under the prevailing conditions. This study provides the first systematic record of freshwater gastropod diversity in a sulfurous spring ecosystem in Sumenep, Madura, establishing a critical baseline for future biodiversity monitoring in chemically stressed spring habitats.

How to Cite: Sidarta, F.S.R., Amabrwati, R., & Isnainingsih, N.R. (2026). Freshwater Snails Diversity and Distribution in the Kaduara Sulfurous Spring, Sumenep, Madura, Indonesia. *Jurnal Riset Biologi dan Aplikasinya*, 8(1), 18-33. <https://doi.org/10.26740/jrba.v8n1.p18-33>.

INTRODUCTION

Gastropods are a class within the phylum Mollusca. Gastropod species inhabit terrestrial, marine, and freshwater environments. Gastropods found in freshwater habitats include snails that live in rivers, streams, lakes, swamps, temporary ponds, rice fields, ponds, and ditches (Takdim & Annawaty, 2019). Freshwater snails have a high number of species, making them a major contributor to faunal diversity in freshwater (Purnama et al., 2022). In their habitat, gastropods become consumers and can be herbivores, carnivores, detritivores, deposit feeders, suspension feeders, and parasites (Susintowati et al., 2019).

In Indonesia, freshwater snails are widespread in all regions, both on large and small islands. In 1959 van Benthem Jutting compiled a number of studies on the diversity of freshwater molluscs from the Malay Peninsula, Sumatra, Java, Kalimantan and several small surrounding islands (Putra et al., 2023). Research on the distribution of freshwater gastropods has also been conducted by Purnama et al. (2022) on freshwater gastropod diversity and distribution in Buton Island, Southeast Sulawesi. Studies on freshwater gastropods in West Java have also been conducted in the Ciapus, Ciliwung, and Cisadane river watersheds, with reports of seven species with the highest diversity recorded at Station 1 ($H' = 1.30$) in the Cisadane river (Ridwan et al., 2025; Marwoto & Isnainingsih, 2014). Studies conducted in sulfurous or geothermally influenced spring habitats elsewhere have consistently reported low species richness, Chatterjee et al. (2022) recorded only *Lymnaea accuminata* from geothermal springs in the Bhagirathi Valley, Garhwal Himalaya, India, noting that this single species preferentially inhabits spring margins due to nutrient availability and physiological tolerance of elevated temperatures. Similarly, *Physella johnsoni* inhabits only seven highly specialized thermal springs and represents a genetically distinct endemic species that diverged approximately 10,000 years ago as an adaptation to this extreme environment (Stanford et al., 2023).

Madura Island is one of the islands in Indonesia which is geographically located in the northeast of Java Island ($6^{\circ}52'-7^{\circ}15'$ LS $112^{\circ}40'-114^{\circ}7'$) with an island length of about 190 km with a widest distance of about 40 km (Ar Razy & Mahzuni, 2021). Madura Island includes 4 districts: Bangkalan, Sampang, Sumenep, and Pamekasan (Ridwanah et al., 2022). Several studies related to freshwater gastropods on Madura Island are rarely found, one of the most frequently found is about marine gastropods in the Pamekasan area (Islamy et al., 2020; Istifadah et al., 2023).

Freshwater snails can be found in various waters on Madura Island, including those in Sumenep Regency (Sriwahjuningsih et al., 2022). The Kaduara Sulfur Spring, located in Sumenep Regency, is sulfur spring water. However, several freshwater snail species have been found there. Studies on the fauna in the sulfur spring area have been limited to planktonic organisms (Kamilah et al., 2014). No study has systematically documented the morphological characteristics or physicochemical associations of freshwater gastropods inhabiting sulfurous spring ecosystems in Sumenep, Madura. Therefore, this study aims to identify freshwater gastropod species present in the Kaduara Sulfur Spring, Sumenep, Madura, describe the morphology and morphometry of each identified species and analyze the relationship between gastropod and the physicochemical parameters of the spring water, including pH, temperature, and sulfur content.

MATERIALS AND METHODS

Sample Collection

Samples were collected on 17 July 2024 during the dry season (April – October) from the Panggulan, East Kaduara, Pragaan, Sumenep Regency, Madura, East Java, with coordinates - 7.123676218655115 , 113.60619027301428 (Figure 1). Sampling was conducted once during this period, as physicochemical parameters including pH, temperature, and sulfur content are relatively stable during the dry season compared to the rainy season, when rainfall may cause significant dilution and fluctuation of spring water chemistry.

Specimens were collected directly using the hand-picking method. Furthermore, the specimens were preserved using 70% alcohol. 250 ml of water sample was collected and submitted to the UPT Pengujian Sertifikasi Mutu Barang – Lembaga Tembakau Surabaya for sulfur content analysis. analyzed for the sulfur content using the gravimetric method following SNI 02-1760-2005 clause 6.1 (Sample No. 0676/NS/VII/2024) resulting in a measured value of 0.077% (equivalent to 770 mg/L total sulfur). Measurement of physicochemical parameters was carried out simultaneously at the research location. The pH of water was measured using a Milwaukee pH meter. Acidic or alkaline levels are generally expressed as pH values and can be measured with a pH meter (Bleam, 2017). Water temperature was measured using a mercury thermometer.

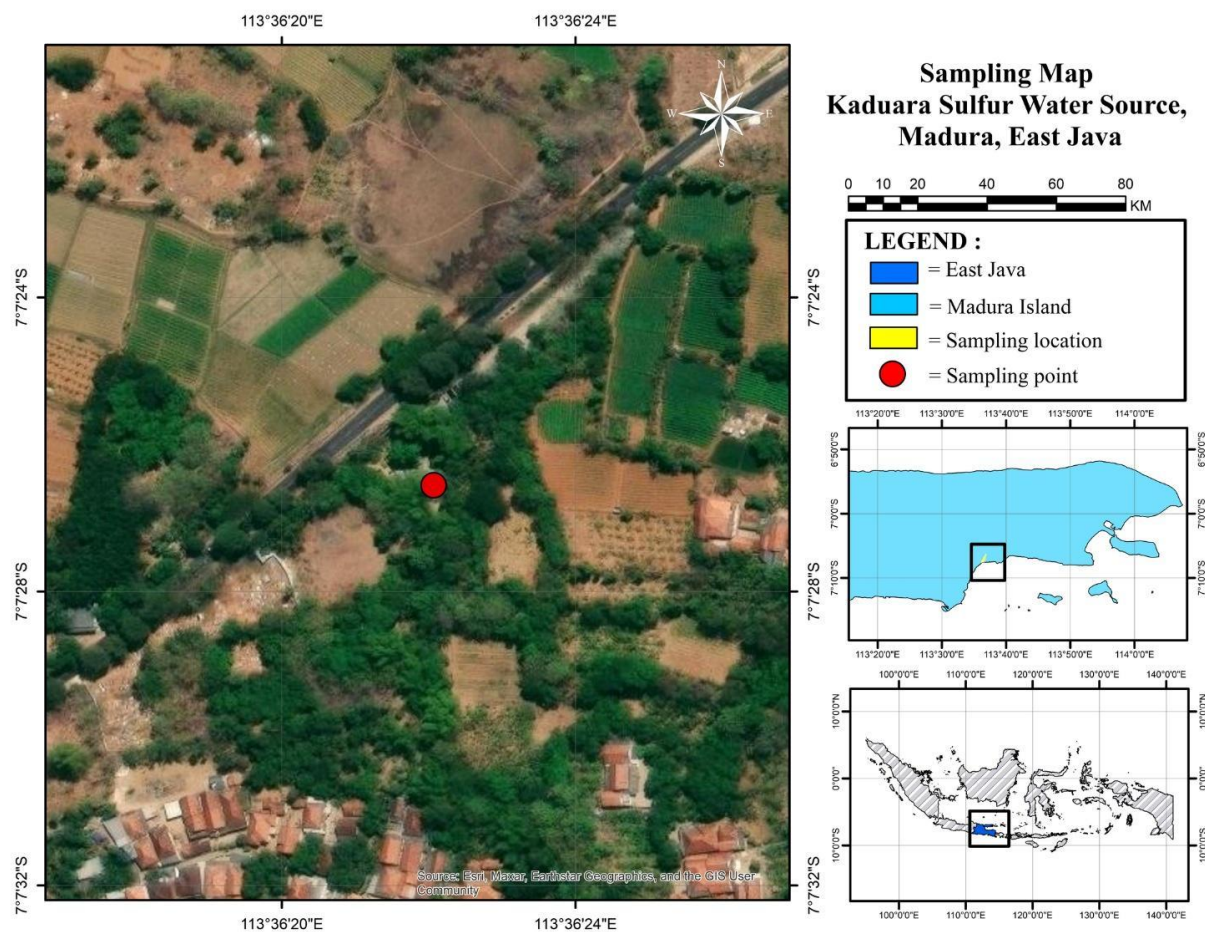


Figure 1. Sampling point at Kaduara sulfur water source, Sumenep, Madura, Indonesia

Morphometric Identification and Measurement

Gastropod specimens were identified based on morphological characters referring to (Dharma, 2005). Species validity was confirmed according to MolluscaBase. Specimens were measured for morphometric parameters using a caliper with an accuracy of 0.05 mm. The morphometric parameters listed in Figure 2 include Shell Length (SL), Shell Width (SW), Spire Height (SH), Aperture Length (AL), Aperture Width (AW), and Body Whorl (BW).

Data Analysis

Data were analyzed descriptively by explaining the conditions of the sampling locations to document the diversity and distribution of freshwater gastropod specimens collected from the Kaduara Sulfurous Spring. The specimens were described for their morphology including shell color, shell shape, shell pattern, shell ornamentation, shell rotation, aperture type, and operculum type. Morphometric measurements were recorded for each specimen and presented as mean values per species. The distribution of each species across sampling points was mapped using coordinate data and presented alongside physicochemical parameters including temperature, pH, and sulfur content due to characterize the habitat conditions at each locality.

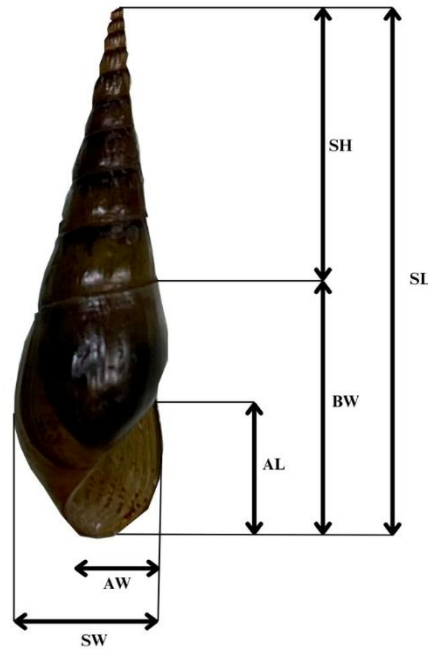


Figure 2. Morphometric measurements of gastropods. Shell Length (SL), shell width (SW), spire height (SH), body whorl (BW), aperture length (AL), and aperture width (AW).

RESULTS AND DISCUSSION

Seven freshwater gastropod species belonging to two families (Thiaridae and Neritidae) were collected from the sulfur water source area, Kaduara, Sumenep Madura. The identified species were *Stenomelania rustica*, *Stenomelania torulosa*, *Stenomelania* sp., *Mieniphotia scabra*, *Melanoides tuberculata*, *Neritina cornuta*, and *Clithon* sp. The following are details about the description and systematics of this species.

Systematics

Kingdom Animalia

Phylum Mollusca

Class Gastropoda

Family Thiaridae

Genus *Stenomelania*

Species *Stenomelania rustica* (Mousson, 1857). (Figure 3)

Melania (Melania) Sondeiana (Martin, 1891).

Material Examined

(LTH.GST.149), (LTH.GST.150), (LTH.GST.151), (LTH.GST.152), (LTH.GST.153)

Collection specimen from Kaduara sulfur water source, Sumenep, Madura. (-7.123676218655115, 113.60619027301428).

Diagnosis

The shell of *Stenomelania rustica* is characterized by elongated shell shape with several clearly visible threads. Shell surface is sculptured with vertical growth lines. The shell color is generally blackish brown to greenish brown.

Description

Shell: Medium to large, Dextral, Threadlike with radial lines, Blackish brown in color, Smooth shell, Deep suture, Operculum oval with straight, Non-thickened outer lip, Aperture narrowly perbani-shaped ; slightly widened at the base ; brownish inside, Umbiculus closed, Number of whorls 9-10, with medium-sized body whorl.

Morphometric

SL: 25.4 - 42.85 mm; SW: 6.1 - 10 mm; SH: 11.1-23.55 mm; BW: 13.3-19.45 mm; AL: 7.1-10.3 mm; AW: 4-6.95 mm.

Species *Stenomelania torulosa* (Bruguère, 1792). (Figure 3)

Stenomelania torulosa (Scheel et al., 2020). (Figure 1)

Material Examined

(LTH.GST.155) Collection specimen from Kaduara sulfur water source, Sumenep, Madura. (-7.123676218655115, 113.60619027301428).

Diagnosis

The shell of *Stenomelania torulosa* is characterized by having a slightly rough surface and spiral growth lines. The shell color varies, usually blackish brown to greenish brown.

Description

Shell: Medium to large, Dextral, Elongated with radial lines, Blackish brown in color, Rough shell, Deep suture, Operculum oval with straight, Non-thickened outer lip, Pyriform aperture ; slightly widened at the base ; brownish inside, Umbiculus closed, Number of whorls 6-8, with medium-sized body whorl.

Morphometric

SL: 30.1 - 36.1 mm; SW: 7.6 - 9.7 mm; SH: 11.75-22.4 mm; BW: 12.6 - 18.7 mm; AL: 7.15 - 10.65 mm; AW: 4.5 - 6.5 mm.

Genus

Mieniplotia

Species *Mieniplotia scabra* (Müller, 1773). (Figure 3)

Buccinum scabrum (Müller, 1773).

Pseudoplotia scabra (Müller, 1773).

Thiara scabra (Müller, 1773).

Material Examined

(LTH.GST.145) Collection specimen from Kaduara sulfur water source, Sumenep, Madura. (-7.123676218655115, 113.60619027301428).

Diagnosis

The shell of *Mieniplotia scabra* is characterized by having a rough surface with pointed protrusions. It has spiral growth lines. The color of the shell is usually blackish brown with darker shades.

Description

Shell: Small, Dextral, Elongated, Black in color, Rough shell, Deep suture, Operculum oval with straight, Non-thickened outer lip, Aperture perbani-shaped ; slightly widened at the base ; brownish Umbiculus closed, Number of whorls 3-5, With medium-sized body whorl.

Morphometric

SL: 12 mm ; SW: 6 mm ; SH: 4.25 mm ; BW: 7.75 mm ; AL: 4.45 mm ; AW: 2.1mm.

Genus

Stenomelania

Species *Stenomelania* sp. (Figure 3)

Material Examined

(LTH.GST.158) Collection specimen from Kaduara sulfur water source, Sumenep, Madura. (-7.123676218655115, 113.60619027301428).

Diagnosis

The shell of *Stenomelania* sp. is characterized by having a smooth surface with a slightly elongated, slender shell. It has spiral growth lines. The color of the shell is usually blackish-brown with darker shades on the shell.

Description

Shell: Medium to large, Dextral, Elongate with radial lines, Brown in color with black lines. Smooth shell, Deep suture, Operculum oval with straight, non-thickened outer lip, Aperture narrowly perbani-shaped; slightly widened at the base; brownish inside, Umbiculus not visible, Number of whorls 8-10, With medium-sized body whorl.

Morphometric

SL: 28.2 - 39.65 mm ; SW: 8 - 10 mm ; SH: 14.8 - 23.1 mm ; BW: 13.4 - 16.55 mm AL: 7.25 - 10.7 mm ; AW: 4.8 - 5.2 mm.

Genus *Melanoides*

Species *Melanoides tuberculata* (Müller, 1773). (Figure 3)

Nerita tuberculata (Müller, 1773).

Melania tuberculata (Müller, 1773).

Thiara tuberculata (Müller, 1773)

Material Examined

(LTH.GST.127) Collection specimen from Kaduara sulfur water source, Sumenep, Madura. (-7.123676218655115, 113.60619027301428).

Diagnosis

The shell of *Melanoides* sp. is characterized by having a smooth surface and a shell-like shape. It has spiral growth lines. The color of the shell is usually blackish brown accompanied by darker shades on the shell.

Description

Shell: Medium to large, Dextral, Elongate with radial lines, Blackish brown in color, Smooth shell, Deep suture, Operculum oval with straight, Non-thickened outer lip, Aperture narrowly perbani-shaped ; slightly widened at the base ; brownish inside, Umbiculus not visible, Number of whorls 6-8, with medium-sized body whorl.

Morphometric

SL: 25 mm; SW: 7.6 mm; SH: 12.7 mm; BW: 12.3 mm; AL: 7.2 mm; AW: 4.1 mm.

Family Neritidae

Genus *Neritina*

Species *Neritina cornuta* (Reeve, 1843). (Figure 4)

Neritina cornuta (Purnama et al., 2022). (Table 1)

Material Examined

(LTH.GST.102) Collection specimen from Kaduara sulfur water source, Sumenep, Madura (-7.123676218655115, 113.60619027301428).

Diagnosis

The shell of *Neritina cornuta* is characterized by having a smooth surface and a round shape with low tendrils. It has spiral growth lines. The color of the shell is usually blackish-brown accompanied by dark shades on the shell.

Description

The shell of *Neritina cornuta* is characterized by having a smooth surface and a round shape with low tendrils. It has spiral growth lines. The color of the shell is usually blackish-brown accompanied by dark shades on the shell.

Morphometric

SL: 13.5 - 16.5 mm; SW: 10.5 - 15 mm; AL: 8.6 - 11.6 mm; AW: 5.5 - 6.5 mm.

Genus *Clithon*

Species *Clithon* sp. (Figure 4)

Material Examined

(LTH.GST.113) Collection specimen from Kaduara sulfur water source, Sumenep, Madura. (-7.123676218655115, 113.60619027301428).

Diagnosis

The shell of *Clithon* sp. is characterized by having a slightly rough and non-glossy surface. It has spiral growth lines. The apex is prominent. The shell color is usually dark brown-black with wide, Whitish columella.

Description

Shell : Small to medium, Round with low spires (Whorl), Black in color, Smooth shell, Columella wide; White in color, smooth, Peristome developed in whitish black color, Operculum semicircular, Moderately deep, Whitish black in color, Aperture semicircular, Umbiculus closed.

Morphometric

SL: 13.5 mm; SW: 12 mm; AL: 8.7 mm; AW: 5.7 mm

Table 1. Environmental parameters at the Kaduara sulfur springs

Measurement	Mean
Temperature	29°C
pH	7
Sulfur Content	770 mg/L

The freshwater gastropods at the Kaduara Sulfur Water Source, Sumenep, Madura, identified five genera across two families. The collected specimens were classified under the genera *Stenomelania*, *Mieniplotia*, *Melanoides* (Family: Thiaridae), *Neritina* and *Clithon* (Family: Neritidae), with the Thiaridae representing the dominant group. A factor contributing to the dominance of Thiaridae populations in aquatic habitats is the parthenogenetic reproduction observed in some species. This trait enables population establishment and growth from a single individual (Surbakti, 2010).

The Thiaridae includes *Stenomelania rustica* (Mousson, 1857), *Stenomelania torulosa* (Bruguère, 1792) and *Melanoides tuberculata*, which have elongated, pointed shells (Figure 3). *Mieniplotia scabra*, has a smaller shell with distinctive spines. These Thiaridae species are generally found in estuarine or brackish water environments (Apiraksena et al., 2020). This group also prefers to live in waters with rocky or sandy bottoms that allow them to attach themselves. Neritidae species have also been reported to inhabit the same habitats as Thiaridae, from river estuaries to downstream areas. At the study site, *Neritina cornuta* (Reeve, 1843) and *Clithon* sp. (Figure 4) were found attached to the back of a rock in accordance with the habitat preferences of this genus, which likes to live on rocky and sandy substrates (Sasaki, 2001; Tan et al., 2008; Feng et al., 2020).

The gastropod species found in Kaduara's sulfur springs include *Melanoides tuberculata*, *Stenomelania rustica*, *Stenomelania torulosa*, *Stenomelania* sp. *Mieniplotia scabra*, *Neritina cornuta*, and

Clithon sp. are likewise common in freshwater environments. This suggests that the abiotic elements in the Kaduara springs remain within normal or tolerable ranges for these taxa. The recorded water temperature of 29°C falls within the survival range of Thiaridae, as Santos & Eskinazi-Sant'Anna (2010) reported that *Melanoides tuberculata* tolerates temperatures between 27.5°C and 30.5°C, Mitchell & Brandt (2005) also recorded Thiaridae survival across 18–32°C. Likewise, the measurement pH of 7 lies within the tolerance range of both families. Thiaridae optimal survival at pH 7.5 – 8.5 (Mitchell & Brandt, 2005). While Neritidae are known to tolerate pH 5 – 9 and temperatures of 27 – 32°C (Hristov, 2020; Chan et al., 2022). Regarding sulfur content, the measured concentration of 770 mg/L represents a naturally elevated level above typical freshwater. No published study has directly tested H₂S tolerance threshold in freshwater gastropods especially in families Thiaridae or Neritidae. However, Küster et al. (2005) showed that the EC₅₀ of H₂S for *Daphnia magna* is 0.12 mg/L, while for microalgae *Scenedesmus vacuolatus* it is 1.8 mg/L. That can be indicating the dissolved H₂S threshold for aquatic invertebrates is far below the total sulfur concentration measured at Kaduara sulfur spring. Furthermore, at pH 7 around half of the total dissolved sulfide in the water exist as bisulfide ion (HS⁻) which is non-toxic to aquatic organisms, meaning the actual concentration of toxic H₂S reaching the gastropods is considerably lower than the total measured sulfur value of 770 mg/L (Lien et al., 2022).

Table 2. Morphometric measurement data of gastropod shells

No	Species	Measurement	n	Range (mm)
1.	<i>Stenomelania rustica</i>	SL	20	25.4 – 42.85
		SW		6.1 – 10
		SH		11.1 – 23.55
		BW		13.3 – 19.45
		AL		7.1 – 10.3
		AW		4 – 6.95
2.	<i>Stenomelania torulosa</i>	SL	15	30.1 – 36.1
		SW		7.6 – 9.7
		SH		11.75 – 22.4
		BW		12.6–18.7
		AL		7.15 – 10.65
		AW		4.5 – 6.5
3.	<i>Mieniplotia scabra</i>	SL	1	12
		SW		6
		SH		4.25
		BW		7.75
		AL		4.45
		AW		2.1
4.	<i>Stenomelania</i> sp.	SL	5	28.2 – 39.65

		SW		8 – 10
		SH		14.8 – 8
		BW		13.4 – 16.55
		AL		7.25 – 10.7
		AW		4.4 – 5.2
5.	<i>Melanoides tuberculata</i>	SL	1	25
		SW		7.6
		SH		12.7
		BW		12.3
		AL		7.2
		AW		4.1
6.	<i>Neritina cornuta</i>	SL	3	13.5 – 16.5
		SW		10.5 – 15
		AL		8.6 – 11.6
		AW		5.5 – 6.5
7.	<i>Clithon</i> sp.	SL	1	13.5
		SW		12
		AL		8.7
		AW		5.7

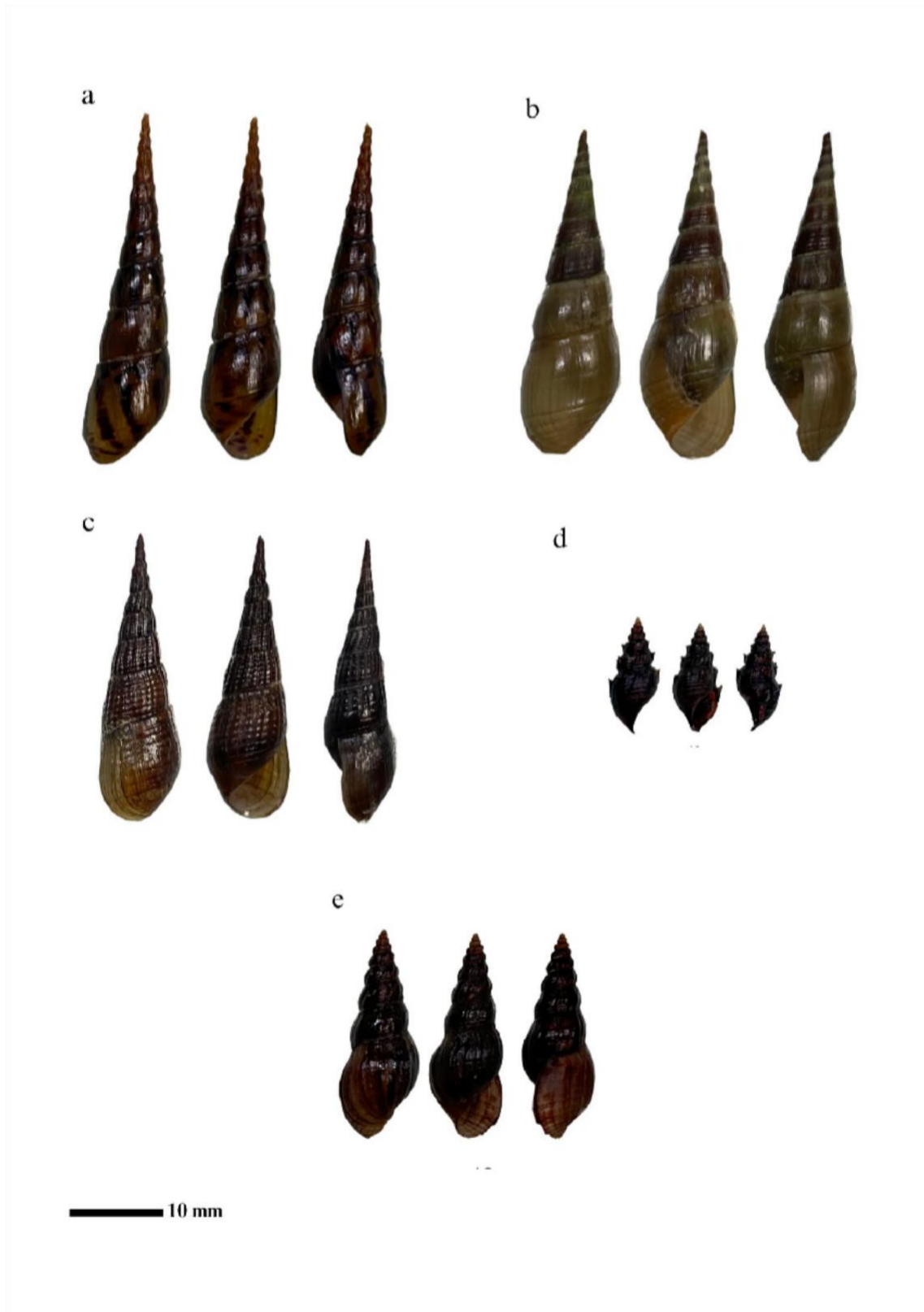


Figure 3. Thiariidae species from Kaduara sulfur spring: (a) *Stenomelania* sp.; (b) *Stenomelania rustica*; (c) *Stenomelani torulosa*; (d) *Mieniplotia scabra*; (e) *Melanoides tuberculata*

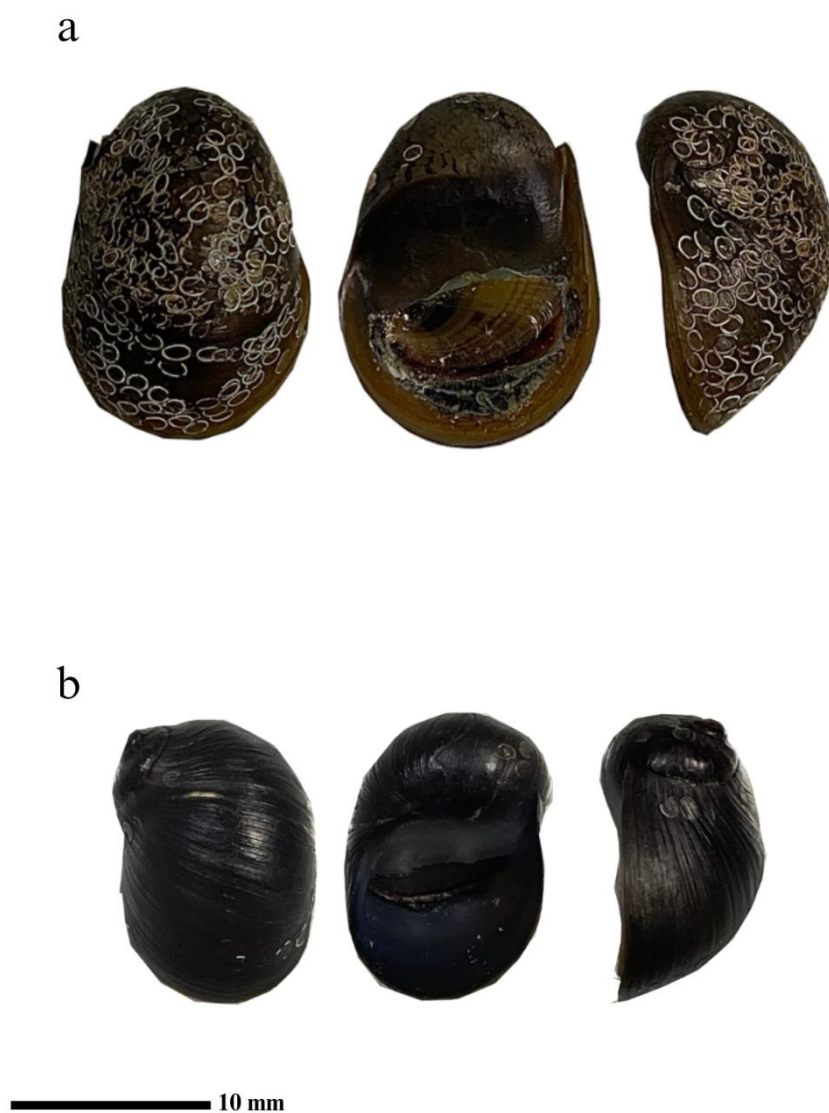
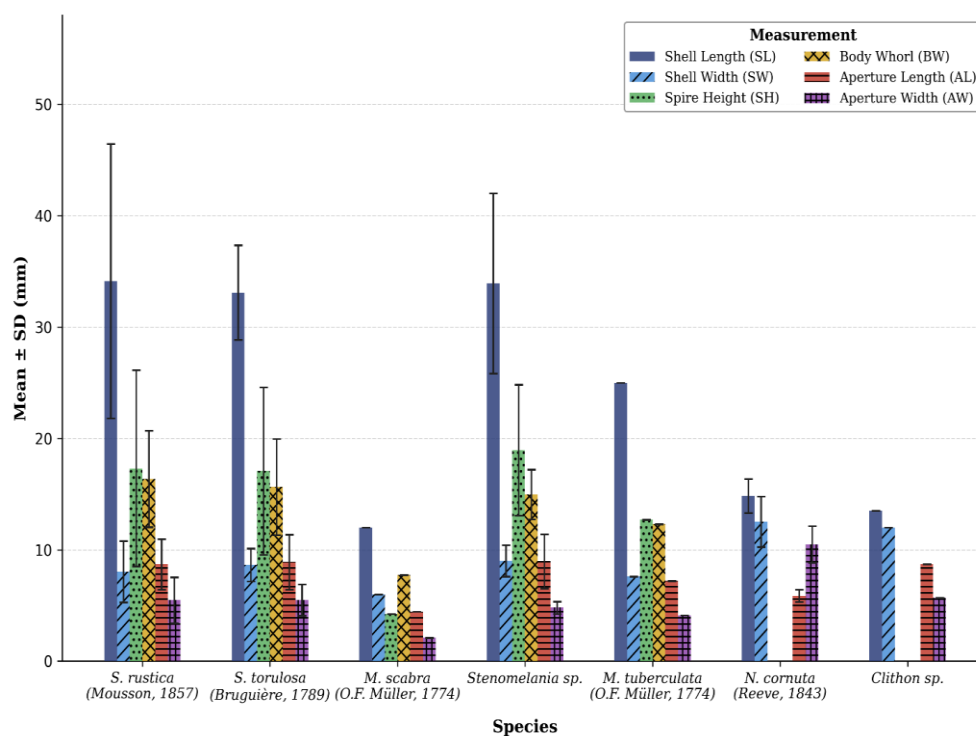


Figure 4. Neritidae species from Kaduara sulfur spring: (a) *Neritina cornuta*; (b) *Clithon* sp.



* SH and BW were not measured for *Neritina cornuta* and *Clithon* sp. (non-turbiniform shell). Species names follow MolluscaBase (2025). Error bars = ± 1 SD.

Figure 5. Morphometric parameters of each species



Figure 6. Habitat of freshwater gastropod in the Kaduara sulfurous spring, Panggulan, Kaduara, Sumenep, Madura

Sulfur is one of the most redox-sensitive elements and has a marked impact on the geochemical cycling of biogenic elements in freshwater sediments (Canfield et al., 1993; Chambers et al., 2000; Couture et al., 2010). Sulfur in its natural form is a yellow crystalline solid. In nature, sulfur can be found as a pure element or as sulfide and sulfate minerals (Rompas et al., 2018). However, the sulfur level of the Kaduara spring is quite low (770 mg/L) a level that is elevated above typical freshwater conditions in the aquatic environment, as evidenced by the measured pH of 7. Therefore, the conditions at the Kaduara sulfur spring are different from those at the Banff National Park (BNP) thermal springs

in Alberta, Canada. The warm thermal spring has a temperature of around 30-38°C and reaches a significant concentration of dissolved minerals, including noticeably high quantities of hydrogen sulfide. These conditions are extreme, with just the snail species *Physella johnsoni* living there. *Physella johnsoni* is an endemic species that lives only in a few thermal springs. All of these springs are in the southern Canadian Rocky Mountains (COSEWIC, 2008). The contrast shows that the level of sulfide stress in a habitat directly determines how many species can live there and what they need to survive. In highly sulfidic environments like BNP, organism must rely on specialized physiological mechanisms to avoid being poisoned by H₂S. The primary way that animals detoxify H₂S is through an enzyme called sulfide quinone oxidoreductase (SQR), which converts toxic H₂S into a harmless sulfate compound inside (Hildebrandt & Grieshaber, 2008). The gastropod recorded at Kaduara consists of cosmopolitan freshwater species with known broad environmental tolerance rather than extreme physiological specialization. *Melanoides tuberculata* has demonstrated broad tolerance to chemical stressors under controlled laboratory conditions, surviving exposure to multiple heavy metals at temperature of 28 - 30°C and neutral pH (Shuhaimi-Othman et al., 2012). Studies on freshwater gastropod community structure in relation to physicochemical gradients have further confirmed that Thiaridae and related families are relatively tolerant to a broad range of environmental stressors including pH variation, dissolved oxygen fluctuation, and elevated nutrient concentrations (Gümüş et al., 2022).

The Kaduara sulfur springs can still provide dwelling space or habitat for various freshwater gastropod species, given that the waters abiotic parameters remain somewhat normal, as in a typical freshwater environment. This is also corroborated by the shell growth of five gastropod species under normal water conditions. *Tarebia granifera* shell heights range from 13.40 mm to 32.15 mm, *M. tuberculata* shell heights range from 15.39 mm to 46.78 mm, and *Stenomelania* shell heights range from 24.30 to 46.78 mm (Isnainingsih et al., 2017; Isnainingsih et al., 2021). However, the physicochemical factors in sulfur-containing habitats influence the survival of living animals in the waterbodies (Fitri et al., 2022). This can affect the metabolism and reproduction of the gastropods that live there. Waters with sulfur concentration levels ranging from 0.03-0.1 are generally considered oligotrophic. Oligotrophic waters, also known as low-fertility waters, are composed of a few organic and inorganic compounds (Wardhana, 2006; Anggraini et al., 2017; Audah et al., 2021). Therefore, monitoring gastropod populations in Kaduara waters is necessary to ensure the survival of each species.

CONCLUSION

Seven freshwater gastropod species were recorded from the Kaduara Sulfurous Spring, Sumenep, Madura: *Stenomelania rustica*, *Stenomelania torulosa*, *Stenomelania* sp., *Mieniphotia scabra*, *Melanoides tuberculata*, *Neritina cornuta*, and *Clithon* sp. The physicochemical conditions of the spring remained within the documented tolerance thresholds of both Thiaridae and Neritidae, providing a physicochemical explanation for the presence of this diverse assemblage in a sulfurous habitat. Morphological and morphometric characterization confirmed that shell dimensions of the recorded species were consistent with published reference ranges, indicating normal growth under the prevailing spring conditions. This study represents the first systematic documentation of freshwater gastropod diversity and distribution in a sulfurous spring ecosystem in Sumenep, Madura, and monitoring gastropod populations in Kaduara waters is required to ensure the survival of each species.

ACKNOWLEDGMENTS

This publication is an output of “MBKM Penelitian Riset 2024” program. The authors are grateful to MBKM Team and especially to the Animal Taxonomy Research Team Universitas Negeri Surabaya, Surabaya, Indonesia. The authors also thank the sampling team for their assistance during the fieldwork and we sincerely thank all institution who supported this research. The measurement of sulfur content was conducted at PSMB-LT laboratory (Pengujian Sertifikasi Mutu Barang–Lembaga Tembakau), for which the authors express their sincere appreciation.

DECLARATIONS

- Author Contributions** : Author 1: Conceptualisation, Methodology, Writing - Original Draft; Author 2: Formal Analysis, Investigation, Review; Author 3: Formal Analysis, Investigation, Review; All authors have read and approved the final manuscript
- Funding** : No funding
- Conflict of Interest** : The authors declare no conflict of interest.
- Data Availability** : The raw morphological data are available from the corresponding author upon reasonable request.
- Ethical Approval** : No ethical approval for this research
- Declaration of AI Use** : AI tools (Gemini and DeepL) were used for spelling checks and grammar corrections. The authors reviewed and take full responsibility for the final content.

REFERENCES

- Anggraini, A., Sudarsono, S., & Sukiya, S. (2017). Plankton abundance and fertility in Bedog River. *Kingdom*, 5(6), 1–9. <https://doi.org/10.21831/kingdom.v5i6.5923>
- Apiraksena, K., Namchote, S., Komsuwan, J., Dechraksa, W., Tharapoom, K., Veeravechsukij, N., Glaubrecht, M., & Krailas, D. (2020). Survey of *Stenomelania* in southern Thailand. *Zoosystematics and Evolution*, 96(2), 807–819. <https://doi.org/10.3897/zse.96.59448>
- Ar Razy, M.R.O., & 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>
- Audah, N., Japa, L., & Yamin, M. (2021). Diatom diversity as pollution bioindicator. *Jurnal Biologi Tropis*, 20(3), 525–531. <https://doi.org/10.29303/jbt.v20i3.2343>
- Bleam, W. (2017). *Soil and Environmental Chemistry*. Edisi ke-2. London: Academic Press.
- Bruguière, J.G. (1792). Histoire naturelle des vers. *Encyclopédie Méthodique* 1. <https://doi.org/10.5962/bhl.title.49857>
- Canfield, D.E., Thamdrup, B., & Hansen, J.W. (1993). Anaerobic degradation of organic matter in coastal sediments. *Geochimica et Cosmochimica Acta*, 57(16), 3867–3883. [https://doi.org/10.1016/0016-7037\(93\)90340-3](https://doi.org/10.1016/0016-7037(93)90340-3)
- Chambers, J.Q., Higuchi, N., Schimel, J.P., Ferreira, L.V., & Melack, J.M. (2000). Decomposition and carbon cycling in tropical forests. *Oecologia*, 122(3), 380–388. <https://doi.org/10.1007/s004420050044>
- Chan, S.H.M., Ong, D.R.Y., Williams, G.A., Crickenberger, S., Loke, L.H.L., & Todd, P.A. (2022). Behaviour broadens thermal safety margins. *Marine Environmental Research* 177: 105618. <https://doi.org/10.1016/j.marenvres.2022.105618>
- Chatterjee, N., Gupta, A.K., Tiwari, S.K., Clemens, S.C., & Sharma, K. (2022). Small size gastropod fauna from the Matli geothermal spring, Bhagirathi Valley, Garhwal Himalaya, Uttarakhand: ecological implications. *Journal of the Geological Society of India*, 98(1), 47–52. <https://doi.org/10.1007/s12594-022-1926-0>
- COSEWIC. (2008). *Assessment and Status Report on the Banff Springs Snail Physella johnsoni*. Ottawa: Committee on the Status of Endangered Wildlife in Canada.
- Couture, R.M., Gobeil, C., & Tessier, A. (2010). Arsenic, iron and sulfur co-diagenesis in lake sediments. *Geochimica et Cosmochimica Acta*, 74(4), 1238–1255. <https://doi.org/10.1016/j.gca.2009.11.028>
- Dharma, B. 2005. *Recent and Fossil Indonesian Shells*. Hackenheim: ConchBooks.
- Feng, J., Guo, Y., Yan, C., Ye, Y., Li, J., Guo, B., & Lü, Z. (2020). Mitochondrial genome comparison of *Nerita*. *Molecular Biology Reports*, 47(10), 7903–7916. <https://doi.org/10.1007/s11033-020-05870-0>
- Fitri, N., Hernawan, H., & Wahjuningsih, S. (2022). Gastropod ecological index as bioindicator. *Journal of Life Sciences*, 4(2), 47–56. <https://doi.org/10.31980/jls.v4i2.2350>
- Gümüş, B.A., Gürbüz, P., & Altındağ, A. (2022). Towards a sustainable world: diversity of freshwater gastropods in relation to environmental factors — a case in the Konya Closed Basin, Türkiye. *Diversity* 14(11), 934. <https://doi.org/10.3390/d14110934>

- Hildebrandt, T.M., & Grieshaber, M.K. (2008). Three enzymatic activities catalyze the oxidation of sulfide to thiosulfate in mammalian and invertebrate mitochondria. *The FEBS Journal*, 275(13), 3352–3361. <https://doi.org/10.1111/j.1742-4658.2008.06482.x>
- Hristov, K.K. (2020). Observations on *Neritina turrita* breeding behaviour under laboratory conditions. *Indian Journal of Pure and Applied Biosciences*, 8(5), 1–10. <https://doi.org/10.18782/2582-2845.8319>
- Islamy, R.A., & Hasan, V. (2020). Checklist of mangrove snails (Mollusca: Gastropoda) in south coast of Pamekasan, Madura Island, East Java, Indonesia. *Biodiversitas*, 21(7), 23–45. <https://doi.org/10.13057/biodiv/d210733>
- Isnainingsih, N.R., Basukriadi, A., & Marwoto, R.M. (2017). Morphology and ontogeny of *Tarebia granifera*. *Treubia*, 44, 1–14.
- Isnainingsih, N.R., Marwoto, R.M., Alfiah, P.R., & Santoso, P.H. (2021). Morphology and reproduction of *Melanoides* and *Stenomelania*. *Berita Biologi*, 20(2), 25–34.
- Istifadah, N., & Imana, L. (2023). Gastropod diversity in the Lembung Beach mangrove ecosystem, Galis District, Pamekasan Regency, Madura. *Journal of Science and Society*, 1(1), 52–58.
- Kamilah, F., Rachmadiarti, F., & Indah, N.K. (2014). Keanekaragaman plankton yang toleran terhadap kondisi perairan tercemar. *LenteraBio*, 3(3), 226–231.
- Küster, E.; Dorusch, F.; Altenburger, R. 2005. Effects of hydrogen sulfide to *Vibrio fischeri*, *Scenedesmus vacuolatus*, and *Daphnia magna*. *Environmental Toxicology and Chemistry* 24(10): 2621–2629. <https://doi.org/10.1897/04-546R.1>
- Lien, E., Valsvik, G., Nordstrand, J.V., Martinez, V., Rogne, V., Hafsås, O., & Aga, M. (2022). The SeaRAS AquaSense™ system: real-time monitoring of H₂S at sub µg/L levels in recirculating aquaculture systems (RAS). *Frontiers in Marine Science*, 9, 894414. <https://doi.org/10.3389/fmars.2022.894414>
- Martin, K. (1891). *Die Fossilien von Java*. Vol. 1. Leiden: Geologisch Rijksmuseum.
- Marwoto, R.M., & Isnainingsih, N.R. (2014). A Review of Freshwater Mollusc Diversity in Several Lakes within the Ciliwung, Cisadane Watershed *Berita Biologi*, 13(2), 181–189.
- Mitchell, A.J., & Brandt, T.M. (2005). Temperature tolerance of the red-rim melania *Melanoides tuberculatus*. *Transactions of the American Fisheries Society*, 134, 126–133. <https://doi.org/10.1577/FT03-178.1>
- Mousson, A. (1857). Novitates Zollingerianae. *Journal de Conchyliologie* 6: 154–164.
- Müller, O.F. (1773). *Vermium Terrestrium et Fluviatiliium Historia*. Vol. 2. Copenhagen: Heineck & Faber.
- Purnama, M.F., Sari, S.F., Salwiyah, H., Abdullah, S.A.K. (2022). Diversity report of freshwater gastropods in Buton Island, Indonesia. *Biodiversitas*, 23(4), 34–45. <https://doi.org/10.13057/biodiv/d230428>
- Putra, A.W., Al Anshari, M., Sukri, N.M., Widarto, T.H., Atmowidi, T., Litaay, M., & Priawandiputra, W. (2023). Diversity and Distribution of Freshwater Gastropods in the Ciapus River, West Java, Indonesia. *Jurnal Sumberdaya Hayati*, 9(4), 145–151. <https://doi.org/10.29244/jsdh.9.4.145-151>
- Reeve, L.A. (1843). *Conchologia Iconica*. Vol. 9. London: Reeve Brothers.
- Ridwan, M., Kadri S, M., Reza S, M., Iqram, M., & Priawandiputra, W. (2025). Composition of freshwater gastropods (Mollusca) in the midstream of the Cisadane River, West Java, Indonesia. *Jurnal Riset Biologi dan Aplikasinya*, 7(2), 118–127. <https://doi.org/10.26740/jrba.v7n2.p118-127>
- Ridwanah, A.A., Nugraheni, E., & Laksono, A.D. (2022). The Role of Educational Attainment in the Utilization of Community Health Centers on Madura Island, East Java, Indonesia. *Jurnal Keperawatan Indonesia Timur* 2(1): 8–17. <https://doi.org/10.32695/jkit.v2i1.278>
- Rompas, C.T., Turangan, A.E., & Riogilang, H. (2018). Effect of Sulfur Mixing on Soil Shear Strength. *Jurnal Sipil Statik*, 6(10), 23–35.
- Santos, C.M., & Eskinazi-Sant'Anna, E.M. (2010). *Melanoides tuberculata* in Brazilian semiarid ecosystems. *Brazilian Journal of Biology*, 70(1), 1–7. <https://doi.org/10.1590/s1519-69842010000100003>
- Sasaki, T. (2001). Shell and operculum microstructure in Neritidae. *Paleontological Research*, 5(1), 21–31. <https://doi.org/10.2517/prpsj.5.21>
- Scheel, C., Gorb, S.N., Glaubrecht, M., & Krings, W. 2020. Distinct radular motion patterns in Mollusca. *Biology Open* 9(10): bio055699. <https://doi.org/10.1242/bio.055699>
- Shuhaimi-Othman, M., Nur-Amalina, R., & Nadzifah, Y. (2012). Toxicity of metals to a freshwater snail, *Melanoides tuberculata*. *The Scientific World Journal*, 2012(1), 125785. <https://doi.org/10.1100/2012/125785>
- Sriwahjuningsih, H.H., & Fitri, N. (2022). Indeks ekologi gastropoda sebagai bioindikator pencemaran air di Ekowisata Situ Bagendit, Garut. *Jurnal Cahaya Mandalika*, 3(1), 33–43. <https://doi.org/10.36312/jcm.v3i1.554>
- Stanford, B.C., Lepitzki, D.A., Taylor, M.K., & Rogers, S.M. (2023). Pooled whole genome sequencing of the endangered Banff Springs Snail, *Physella johnsoni*, reveals genetic separation to *P. gyrina* and cryptic micro-geographical genetic structure. *Conservation Genetics*, 24(6), 783–791. <https://doi.org/10.1007/s10592-023-01538-x>
- Surbakti, S.B.R. (2010). *Ecology and Phylogeography of Freshwater Snails (Thiaridae) in Papua*. Depok: Universitas Indonesia.

- Susintowati, S., Puniawati, N., Poedjiraharjo, E., Handayani, N.S.N., & Hadisusanto, S. (2019). The intertidal gastropods (Gastropoda: Mollusca) diversity and taxa distribution in Alas Purwo National Park, East Java, Indonesia. *Biodiversitas*, 20(7), 23–45. <https://doi.org/10.13057/biodiv/d200731>
- Takdim, R.R., & Annawaty, A. (2019). Diversity and Abundance of Freshwater Snails (Mollusca: Gastropoda) in the *Pomua Palandu* and *Toinasa Rivers*, Poso, Sulawesi, Indonesia. *Natural Science: Journal of Science and Technology*, 8(2), 144–152.
- Tan, S.K., & Clements, R. (2008). Taxonomy and distribution of the Neritidae in Singapore. *Zoological Studies*, 47(4), 481–494.
- Wardhana. (2006). *Metoda Prakiraan Dampak dan Pengelolaannya pada Komponen Biota Akuatik*. Jakarta: Universitas Indonesi