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Diversity of gastropods (Animalia: Mollusca) in the upper Bengawan Solo River, Central Java, Indonesia: Native versus alien species

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Abstract. *Reza AD, Mahendra AS, Riadi AA, Aryanto AEP, Agustin HN, Dewangga A, Indrawan M, Dadiono MS, Setyawan AD. 2024. Diversity of gastropods (Animalia: Mollusca) in the upper Bengawan Solo River, Central Java, Indonesia: Native versus alien species. Intl J Bonorowo Wetlands 14: 83-95.* Bengawan Solo River in Java Island, Indonesia, is important habitat for aquatic organisms, one of which is gastropods. However, there is indication of the presence of invasive alien gastropods in this river, which might pose threat to native species. This study aimed to identify the diversity of gastropod species in the upper Bengawan Solo River, Central Java, Indonesia and assess the presence of invasive species measured. Data collection was conducted in December 2023 at five stations representing varying habitat conditions. Data was collected using the transect plot method and analyzed by calculating the Shannon-Wiener index, Simpson's dominance index and density. The invasive status of species was determined based on literature studies. The study revealed 23 gastropod species from 9 families. There were 16 invasive species found, including *Tarebia granifera*, *Sulcospira testudinaria, Faunus ater, Achatina immaculata, Pomacea canaliculata*, *Sermyla riquetii*, *Limicolaria flammea*, *Littorina littorea*, *Perpolita hammonis, Viviparus glacialis, Viviparus viviparus*, *Viviparus intertextus*, *Semisulcospira libertina*, *Brotia costula*, *Zebrina detrita,* and *Melanoides tuberculata*. There were 7 native species found, namely *Pila scutata, Pila ampullacea, Filopaludina javanica, Stenomelania punctata, Stenomelania denisoniensis*, *Cipangopaludina chinensis* and *Acavus phoenix*. The level of diversity of gastropod species in the upper Bengawan Solo River was in the medium category while the dominance index was low, indicating that there was no dominant gastropod in the upper Bengawan Solo River. Some invasive gastropod species had high density compared to other species, implying a threat to the native ones. This finding warrants attention since the dominance of invasive alien species can affect the ecological system balance and lead to the loss of native species.

Keywords: Diversity, dominance, gastropods, invasive, upper Bengawan Solo River

INTRODUCTION

Bengawan Solo River is the longest river system in Java Island, Indonesia, which administratively crosses two provinces: Central Java and East Java with a drainage area of 16,000 km^2 (Utomo et al. 2017). It plays important role in various aspects of human livelihoods such as fisheries, agriculture, industry, tourism, and other domestic interests (Mudjib and Lasminto 2013; Firmansyah et al. 2020). The upstream area of the Bengawan Solo River covers several districts in Central Java Province including Wonogiri, Sukoharjo, Surakarta, Karanganyar, and Sragen. The upstream area of Bengawan Solo River is important in maintaining biodiversity, yet it has undergone many changes compared to other rivers in Indonesia such as the construction of reservoirs, canals (*sodetan*), and dams (Darmawan et al. 2018). In particular, these changes affect the diversity and abundance of aquatic organisms formerly occurring in the upper Bengawan Solo River, including gastropods or snail groups (Aida et al. 2022).

Gastropods are an invertebrate group that belongs to the phylum Mollusca. They have soft bodies, use the abdomen for moving, and generally have shells. Gastropods generally have a threaded single shell and eyes, and are equipped with tentacles. They play a crucial role as bioindicators, which can indicate pollution in aquatic ecosystems. In unpolluted waters with low water discharge, gastropods are evenly distributed with great abundance. Conversely, in polluted waters, few gastropod species tend to dominate a habitat (Nurlina and Harahap 2023). Substrates and elements of contaminants affect the composition and diversity of gastropods (Ferisandi et al. 2018).

According to Wahyuningsih and Umam (2022), species distribution is determined by two factors, namely the availability of resources and the presence of barriers or obstacles. Gastropods have a wide range of habitat distribution. They can be found in various water ecosystems, ranging from flowing waters such as rivers to stagnant waters such as lakes, swamps, and reservoirs (Fernanda 2021). Gastropods are also found in various substrates; some are attached to river banks and plants and live in mud, rocks, gravel, and sand (Purnama et al. 2022a). Nonetheless, the existence of gastropods is strongly influenced by food availability and tidal conditions (Uribe et al. 2016).

Gastropods are widely used by local communities as a food source (Sundalian et al. 2022). However, native gastropod species are slowly being degraded by the presence of invasive alien species. These invasive gastropod species tend to compete, dominate and usually attack native species, posing a significant threat to the ecosystem equilibrium (David et al. 2017). In addition, invasive species can reproduce quickly without copulating with the opposite sex; thus, spreading invasive species can dominate water ecosystem and threaten biodiversity. Invasive alien species are also the direct cause of biodiversity loss in the world, through the homogenization process.

There are several studies in the topics of biodiversity in the upper Bengawan Solo River, including Hasan et al. (2023); Haqqi et al. (2024); and Pramono et al. (2024). Nonetheless, there is no analysis which focuses on the presence of gastropods in this area and the potential threat of invasive gastropod species. Given these scientific gaps, this study aims to identify the diversity of gastropod species and their potential invasiveness in the upper Bengawan Solo River. The results of this study is expected to provide insights into the diversity and dominance of gastropod species, distinguish between native and invasive species and identify environmental factors influencing their distribution in the upper Bengawan Solo River.

MATERIALS AND METHODS

Study period and area

The research was conducted on December 2023 in the upper Bengawan Solo River, Central Java Province, Indonesia (Table 1; Figures 1 and 2). Data was collected at five stations representing varying habitat conditions. Station 1 was located in Wonogiri District (Pokoh, Wonogiri, and Giritirto, Wonogiri) with muddy environmental conditions, and there were many cultivated plants on the river banks, such as cassava. Station 2 was located in Sukoharjo District (Colo Dam, Nguter, Sukoharjo, and Bacem Bridge, Grogol, Sukoharjo) with muddy and rocky environmental conditions, many aquatic plants and artificial infrastructure in the form of dams and embankments. Station 3 was located in Surakarta City (Jurug Bridge, Jebres, Surakarta and Kampung Sewu, Jebres, Surakarta) with muddy bank conditions and riverbanks were in the form of grassy floodplains with many aquatic plants. Station 4 was located in Karanganyar District (Ring Road Bridge, Dalon, Sroyo, Jaten, Karanganyar, and Ngabeyan, Kebakkramat, Karanganyar) with muddy conditions and covered with plants on the riverbanks. Station 5 was located in Sragen District (Sidokerto, Plupuh, Sragen and Pringanom, Masaran, Sragen), where conditions were muddy and the riverbanks were overgrown with plants.

Table 1. Geographical coordinates of study location in the upper Bengawan Solo River, Central Java Province, Indonesia

Station	District/city	Location	Coordinates
1A	Wonogiri	Outlet of Gajah Mungkur Reservoir, Karang Talun, Pokoh Kidul	7°49'59.42"S and 110°55'34.78"E
1B		Outlet of Gajah Mungkur Reservoir, Sukorejo, Giritirto	7°49'32.23"S and 110°55'33.61"E
2A	Sukoharjo	Colo Dam, Dusun III, Pengkol, Nguter	7°45'3.82"S and 110°53'58.02"E
2B		Bacem Bridge, Dusun II, Telukan, Grogol	7°36'48.71"S and 110°49'11.61"E
3A	Surakarta	Jurug Bridge, Pucangsawit, Jebres	7°33'59.62"S and 110°51'39.87"E
3B		Demangan Baru Sluice, Kampung Sewu, Jebres	7°34'36.59"S and 110°50'41.16"E
4A	Karanganyar	Ring Road Bridge, Dalon, Sroyo, Jaten	7°32'45.60"S and 110°52'19.46"E
4B		Near pig farm, Kanten, Sroyo, Jaten	7°31'27.19"S and 110°52'28.79"E
5A	Sragen	Masaran Bridge, Dusun I, Sidokerto, Plupuh	7°29'22.20"S and 110°53'35.31"E
5B		Sari Bridge, Dungus, Karanganyar, Plupuh	7°26'47.54"S and 110°54'56.20"E

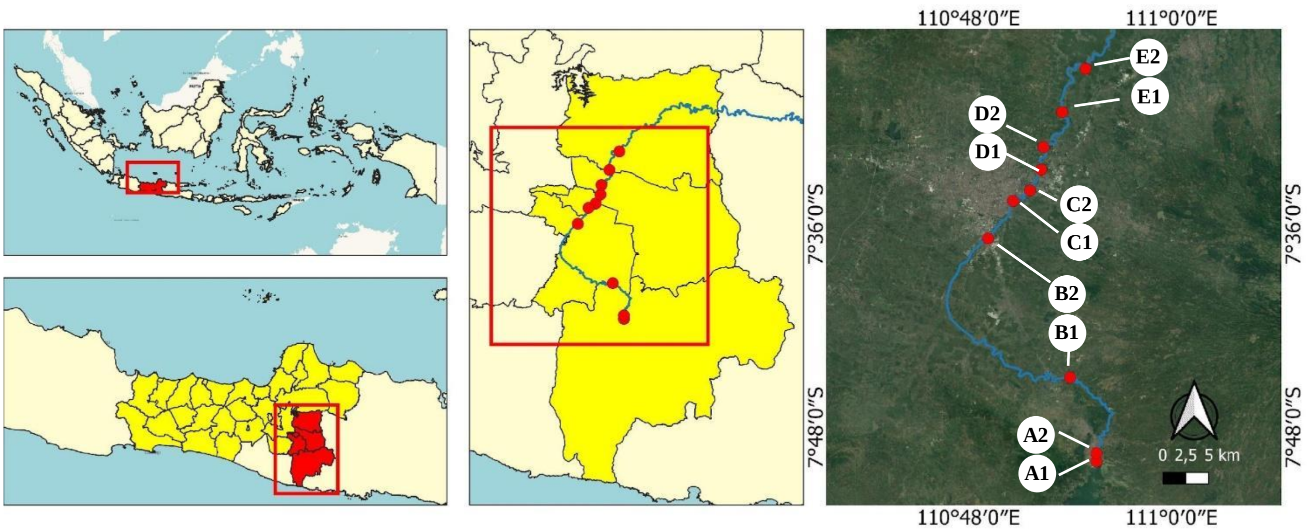

Figure 1. Map of study location in the upper Bengawan Solo River, Central Java Province, Indonesia. See Table 1 for more details

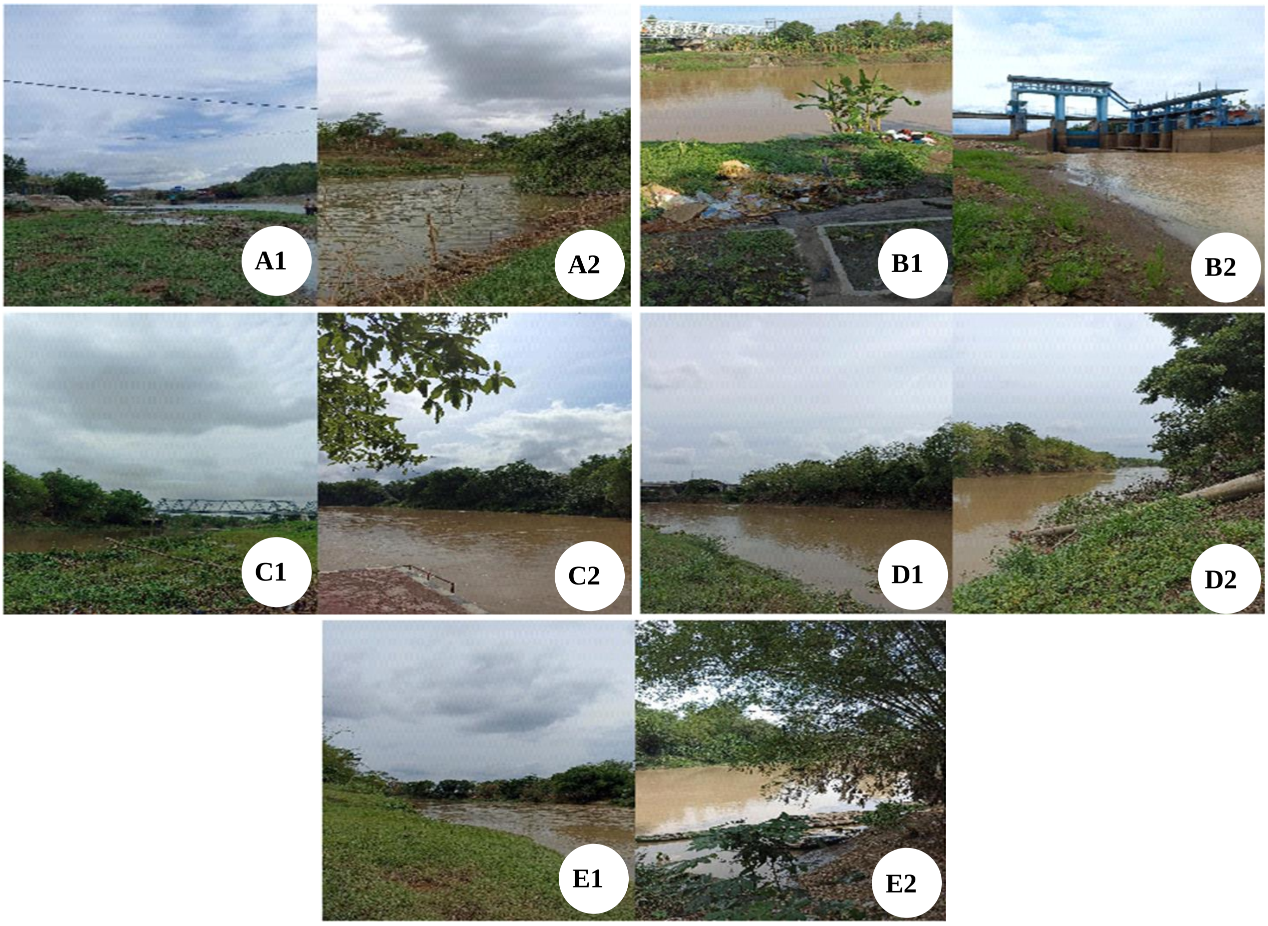

Figure 2. Condition of study location in upper Bengawan Solo River, Central Java Province, Indonesia. A. Station 1: Wonogiri; B. Station 2: Sukoharjo; C. Station 3: Surakarta; D. Station 4: Karanganyar; E. Station 5: Sragen. See Table 1 for more details.

Gastropod sample collection and identification

Sampling was carried out using a purposive sampling method with transect plots based on the conditions on the riverbank (Wahyuningsih and Umam 2022). Each sampling station consisted of two 70-meter transects along the river flow, with 2 × 2 m plots placed at a distance of 5 m between each plot (Hartati et al. 2022). Samples of living gastropods were collected and preserved with 70% alcohol, and gastropod shells were collected and then put into plastic bags for further identification. The identification process was carried out by focusing on the morphological characteristics of the gastropod samples, including shell shape, color, and pattern. After the species identification, the samples were documented using a digital camera. The determination of invasive and native gastropod species was carried out by referring to various references including Veeravechsukij et al. (2018); Wei et al. (2018); Maldonado and Martín (2019); Arias et al. (2020); David et al. (2020); Qin et al. (2020); Envin et al. (2020); Kalcheva et al. (2020); Marwoto et al. (2020); Rodrigo and Manamendra-Arachchi (2020); Sawada et al. (2020); Sánchez et al. (2021); Willan and Kessner (2021); Edgar et al. (2022); Gusna GM et al. (2022); Gurumayum (2023); Ouedraogo et al. (2023); Wang et al. (2023).

Data analysis

Gastropod samples that have been collected and identified were then analyzed. Data analysis of the number of species and individuals of each species collected was carried out using the Shannon-Wiener index (H') to determine the diversity of gastropods, Simpson's dominance index (C) to determine the gastropod dominance level, and density index (Di) to determine the gastropod density. The value of each index calculation is as follows:

The Diversity Index was calculated using the Shannon-Wiener formula (Krebs 1989) as follow:

$$H' = \sum_{i=1}^{s} [(ni/N) \; X \; ln \; (ni/N)]$$

Where: H': Diversity index; ni: Number of individuals of the i-th species; N: Total number of individuals

Shannon-Wiener diversity index is divided into 3 categories, namely:

H'<1: Low diversity; 1<H'≤ 3: Medium diversity; H'>3: High diversity

The Simpson's dominance index was calculated referring to Odum (1949) using the formula:

$$C = \sum_{i=1}^{s} (\frac{ni}{N})^2$$

Where: C: Dominance index; ni: Number of individuals of the i-th species; N: Total number of individuals

The dominance index was classified into two:
$0<C\leq 0.5$: No species dominates; $0.5<C<1$: There is a dominating species

The gastropod density was calculated using the formula (Krebs 1989) as follow:

$$Di = \frac{ni}{A}$$

Where: Di: Density of individuals of the i-th species; ni: Number of individuals of the i-th species; A: Area of the sampling plot (m^2)

The data were then analyzed descriptively. The potential threats of invasive species were analyzed and described based on literature studies.

RESULTS AND DISCUSSION

Gastropods diversity

In total, there were 23 gastropod species belonging to 9 families in the upper Bengawan Solo River obtained from station 1 Wonogiri (9 species), station 2 Sukoharjo (9 species), station 3 Surakarta (10 species), station 4 Karanganyar (5 species), and station 5 Sragen (12 species). Thiaridae is the family with the largest number of species (7), followed by Viviparidae (5 species) and Ampullariidae with 3 species. Other families were represented by one species, including Littorinidae, Achatinidae, Pachychilidae, Achavida, Enidae and Gastrodontidae.

Gastropod species found at station 1 (Wonogiri) were *Tarebia granifera* (Lamarck, 1816), *Pomacea canaliculata* (Lamarck, 1822), *Melanoides tuberculata* (O.F.Müller, 1774), *Filopaludina javanica*, *Sermyla riquetii* (Grateloup, 1840), *Sulcospira testudinaria* Busch, 1842, *Stenomelania denisoniensis* (Brot, 1877), *Semisulcospira libertina* (A.Gould, 1859), and *Viviparus intertextus*. At station 2 (Sukoharjo), various species of gastropod were found, namely *T. granifera*, *S. testudinaria*, *S. libertina*, *P. canaliculata*, *Brotia (Brotia) costula* (Rafinesque, 1833), *Stenomelania punctata* (Lamarck, 1822), *F. javanica*, *Pila ampullacea*, and *M. tuberculata*. At station 3 (Surakarta) the gastropod species included *Pila scutata* (Mousson, 1848), *P. canaliculata*, *Faunus ater* (Linnaeus, 1758), *Limicolaria flammea* (O.F.Müller, 1774), *S. testudinaria*, *F. javanica*, *Achatina immaculata*, *Acavus phoenix* (L.Pfeiffer, 1854), *Perpolita hammonis* (Strøm, 1765), and *T. granifera*. At station 4 (Karanganyar), there were *T. granifera*, *P. canaliculata*, *S. libertina*, *A. immaculata*, and *M. tuberculata*. At station 5 (Sragen), gastropod found were *Viviparus viviparus* (Linnaeus, 1758), *P. canaliculata*, *T. granifera*, *Littorina littorea* (Linnaeus, 1758), *Viviparus glacialis* (S.V.Wood, 1872), *F. javanica*, *P. ampullacea*, *S. testudinaria*, *Cipangopaludina chinensis* (J.E.Gray, 1833), *A. immaculata*, *M. tuberculata*, and *Zebrina detrita* (O.F.Müller, 1774). Some gastropods are presented in Figure 3.

Table 2 shows that not all types of gastropod species can be found at all stations. This is similar to the research of Siswansyah and Kuntjoro (2023) that not all species of gastropods can live at a wide range of habitat because the water and substrate conditions are not suitable for their growth and survival. Nonetheless, *T. granifera* and *P. canaliculata* were found in all stations and easily adapt to the water quality of Wonogiri, Sukoharjo, Surakarta, Karanganyar, and Sragen.

The habitat of *T. granifera* is in lotic waters; it belongs to a form of fauna that lives attached to various types of substrates and is often found on the banks of river waters (Veeravechsukij et al. 2018). In addition to living in natural places, *T. granifera* can be found in man-made water bodies such as reservoirs or water irrigation channels (Majdi et al. 2022). According to research by Albarrán-Mélzer et al. (2020), the species can live between 20 and 38°C. *Tarebia granifera* can adapt to high turbidity and polluted water, so it's widely distributed. It can also be passively carried by river currents, water birds, etc. (Salwiyah et al. 2022). *Tarebia granifera* is considered as invasive alien species, its presence is often used as bioindicators of water pollution (Yakovenko et al. 2018).

Pomacea canaliculata, or gold snail species, can be easily found in various places, such as rice fields, rivers, lakes, and reservoirs (Noorshilawati et al. 2020). In its development at the age of 6 months, it can lay up to approximately 1000 eggs (Harahap et al. 2020). *P. canaliculata* is included in omnivores, which can eat dead animals, and in the food chain and it is included as predator (Kannan et al. 2020). The suitable temperature to adapt to its habitat is 23-32°C (Bae et al. 2021).

Filopaludina javanica, often known as *tutut*, is commonly consumed by human. It is a species that can adapt and survive in river waters with a temperature of 23-32°C, and even with heavy metals presence, such as Cu, Cr, Fe, Mn, Pb, and Zn (Arfiati et al. 2021). The average size of *F. javanica* shell height is between 15 to 35 mm, shell width is 12 to 25 mm and thickness is between 0.13-1 mm (Priawandiputra et al. 2020). *Sermyla riquetii* has similarities with *T. granifera*, which can survive at 20-38°C, and the shell structure is rough and wavy, only half of the shell color is white mixed with brownish (Lentge-Maaß et al. 2021). It is also included as invasive alien species (Wei et al. 2018).

Sulcospira testudinaria has a dark black or black mixed with a brownish color and has a different shell from the *M. tuberculata*. *Sulcospira testudinaria* has a blunt shell at the top and can live at 25-32°C (Arumsari and Adharini 2021). According to Nugroho et al. (2023), *S. testudinaria* has benefits in its shell because there is a potential source of calcium precursors; the shell is rich in calcium carbonate ($CaCO_3$), which can be thermally decomposed into calcium oxide (CaO) through calcination (Mujiono et al. 2019).

Table 2. Presence of invasive and native gastropod species in the Upper Bengawan Solo River, Central Java, Indonesia

Family	Species name	Station					Substrate	Natural distribution	Invasive v.s. native
		1	2	3	4	5			
Thiaridae	*Tarebia granifera* (Lamarck, 1816)	●	●	●	●	●	Mud	Southeast Asia	Invasive (Veeravechsukij et al. 2018)
Ampullariidae	*Pomacea canaliculata* (Lamarck, 1822)	●	●	●	●	●	Lithophytic, plants	South America	Invasive (Qin et al. 2020).
Thiaridae	*Semisulcospira libertina* (A. Gould, 1859)	●	●		●		Lithophytic, mud	Japan	Invasive (Sawada et al. 2020)
Thiaridae	*Melanoides tuberculata* (O.F. Muller, 1774)	●	●		●	●	Lithophytic, mud	Africa	Invasive (Ouedraogo et al. 2023)
Viviparidae	*Filopaludina javanica* (Busch, 1844)	●	●	●		●	Mud	Indonesia, Thailand	Native (Maldonado and Martín 2019)
Thiaridae	*Sulcospira testudinaria* (Busch, 1842)	●	●	●		●	Lithophytic	Indonesia	Native (Hertika et al. 2023)
Thiaridae	*Stenomelania punctata* (Lamarck, 1822)		●				Plants, mud	Indonesia	Native (Willan and Kessner 2021)
Thiaridae	*Stenomelania denisoniensis* (Brot, 1877)	●					Lithophytic	Indonesia	Native (Willan and Kessner 2021)
Viviparidae	*Viviparus intertextus* (Say, 1829)	●					Lithophytic	Latin America	Invasive (Arias et al. 2020)
Thiaridae	*Sermyla riquetii* (Grateloup, 1840)	●					Lithophytic, plants	Thailand	Invasive (Wei et al. 2018)
Ampullariidae	*Pila scutata* (Mousson, 1848)			●			Lithophytic, plants	Indonesia, Myanmar, Thailand	Native (Marwoto et al. 2020)
Ampullariidae	*Pila ampullacea* (Linnaeus, 1758)		●			●	Lithophytic, mud	Indonesia, Singapore	Native (Marwoto et al. 2020)
Pachychilidae	*Faunus ater* (Linnaeus, 1758)			●			Lithophytic	Philippines	Invasive (Gusna et al. 2022)
Achatinidae	*Limicolaria flammea* (O.F. Muller 1774)			●			Plants, lithophytic	West Africa	Invasive (Envin et al. 2020)
Achatinidae	*Achatina immaculata* (Lamarck, 1822)			●	●	●	Plants, lithophytic	Africa	Invasive (Wang et al. 2023)
Achavida	*Acavus phoenix* (L. Pfeiffer, 1854)			●			Plants, lithophytic	Sri Lanka	Invasive (Rodrigo and Manamendra-Arachchi 2020)
Gastrodontidae	*Perpolita hammonis* (Strom, 1765)			●			Plants, lithophytic	North America	Invasive (Sánchez et al. 2021)
Viviparidae	*Viviparus viviparus* (Linnaeus, 1758)					●	Plants, lithophytic	East Russia	Invasive (David et al. 2020)
Viviparidae	*Cipangopaludina chinensis* (J.E.Gray, 1833)					●	Plants, lithophytic	Indonesia, China	Native (Edgar et al. 2022)
Littorinidae	*Littorina littorea* (Linnaeus, 1758)					●	Mud	Russia	Invasive (Moisez et al. 2020)
Viviparidae	*Viviparus glacialis* (S.V. Wood, 1872)					●	Plants	United Kingdom	Invasive (David et al. 2020)
Enidae	*Zebrina detrita* (O.F. Muller, 1774)					●	Lithophytic, mud	European	Invasive (Kalcheva et al. 2020)
Pachychilidae	*Brotia costula* (Rafinesque, 1833)		●				Lithophytic	Southeast Asia	Invasive (Gurumayum 2023)

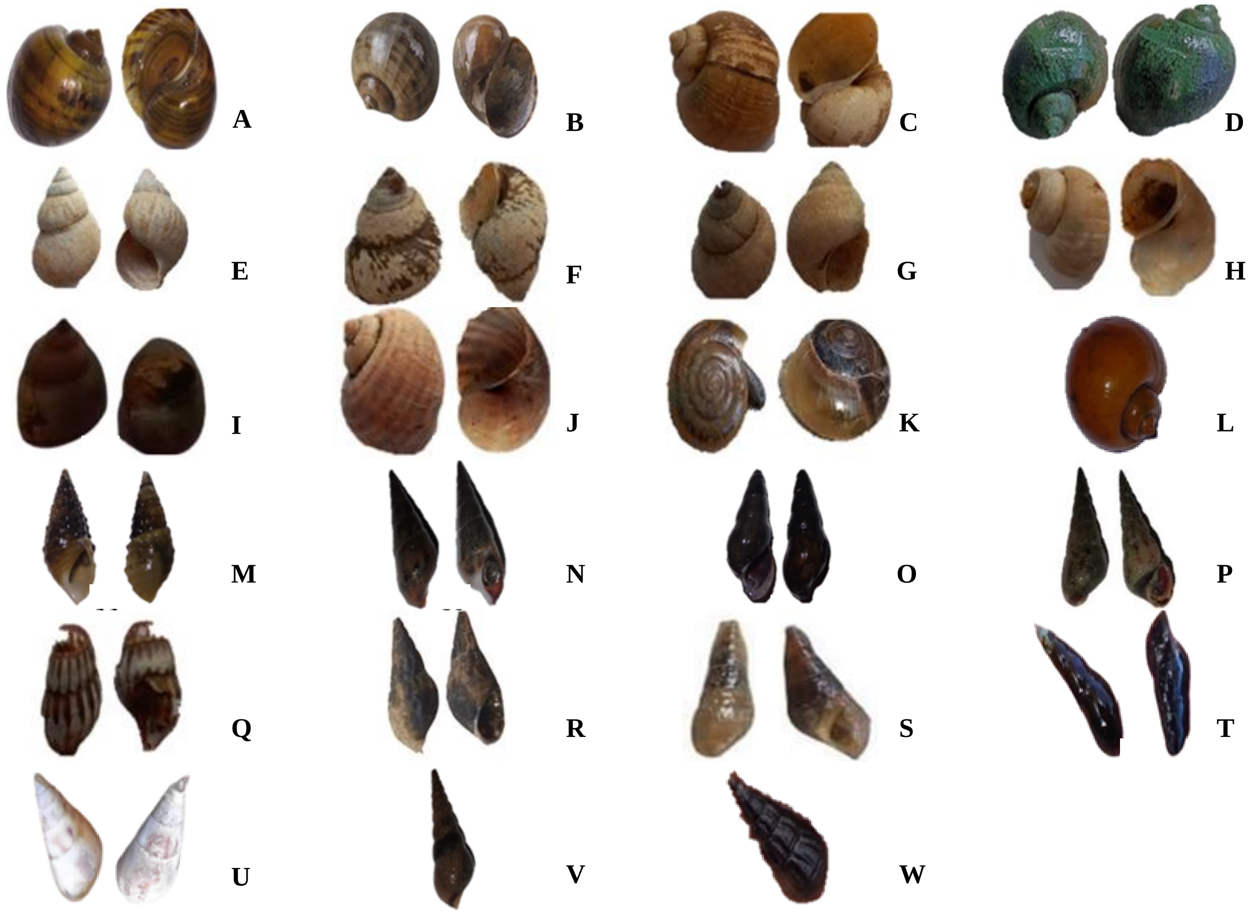

Figure 3. Various species of gastropods found in the upper Bengawan Solo River, Central Java, Indonesia: A. *Pomacea canaliculata*, B. *Viviparus intertextus*, C. *Pila ampullacea*, D. *Acavus phoenix*, E. *Viviparus glacialis*, F. *Achatina immaculata*, G. *Filopaludina javanica*, H. *Cipangopaludina chinensis*, I. *Viviparus viviparus*, J. *Littorina littorea*, K. *Perpolita hammonis*, L. *Pila scutata*, M. *Tarebia granifera*, N. *Faunus ater*, O. *Sulcospira testudinaria*, P. *Melanoides tuberculata*, Q. *Zebrina detrita*, R. *Sermyla riquetii*, S. *Semisulcospira libertina*, T. *Stenomelania denisoniensis*, U. *Limicolaria flammea*, V. *Stenomelania punctata*, W. *Brotia costula*

Stenomelania denisoniensis and *S. punctata* can survive at 20-38°C (Negus et al. 2021); it is often found in dense or sandy mud. However, based on their distribution, *Stenomelania* gastropods are distributed by sea from India to East Asia Island (Apiraksena et al. 2020). Different with *T. granifera*, this species is native species (Negus et al. 2021). *Semisulcospira libertina* has similarities with other species, such as *S. denisoniensis*. The shell structure is rough-patterned, small, brownish, mixed with greenish and black, and does not have a sharp shell on top. This species can live at 20-38°C in freshwater like rivers. Regarding benefits, the industrial sector often uses it to determine water pollution (Sano et al. 2022).

Melanoides tuberculata of Thiaridae family and *B. costula* of Pachychilidae family, can survive at 20-38°C (Nguyen et al. 2021). *Melanoides tuberculata* and *B. costula* are similar in size, which is long like a trumpet and green in color mixed with brown and black; but their structure is different. *Melanoides tuberculata* has a smooth shell and *B. costula* has a rough shell. Its benefits are often used as a source of animal protein (Oktavia et al. 2022). *Achatina immaculata* and *L. flammea* have similarities but differ in the shells' color. The color of *A. immaculata* is brownish mixed with green, and *L. flammea* has a black, brownish color mixed with white. Both species live in aquatic habitats with lithophytic substrates and plants. On the other hand, it is often found on riverbanks with humid environmental conditions and cold temperatures around 20-38°C, like other gastropods (Ehigie et al. 2020; Bohatá and Patoka 2023). The main benefit of *A. immaculata* and *L. flammea* is to provide additional nutrients for catfish farming (Mainisa 2019).

Acavus phoenix can live in water and on land (Salvador 2022). Its color is brownish mixed with white, and it has a similar shell to *V. intertextus*. The species is invasive but does not negatively affect other species. *Viviparus viviparus* and *V. glacialis* are snails living in freshwater waters and can survive with other species of gastropods from 20 to 38°C (Aini et al. 2020). Both species belong to the Viviparidae family of lithophytic substrates or plants. There are such differences, i.e. *V. viviparus* is brownish and blackish, while *V. glacialis* is white. Based on their habitat, they are included in the aquatic category (Preece et al. 2020). *Cipangopaludina chinensis* has a bright brownish shell color when exposed to sunlight; the species is often found on riverbanks with lithophytic substrates or plants to find food and lay eggs (Kingsbury et al. 2020). The shell of this species are often used for accessories (Sundalian et al. 2022). *Faunus ater* has a trumpet-like shell shape with a brownish color and live under the temperature of 20-38°C (Kurniawati et al. 2023). *Faunus ater* existence is rare, the species is only found in many sandy, rocky, and muddy places (Dewi et al. 2022).

Pila ampullacea has a flat but pointed shell shape with brown and blackish colors (Ng et al. 2020). It has positive properties, such as protein, calcium, etc., so the surrounding community often uses it for consumption to increase the immune system (Puspitasari et al. 2022). *Pila scutata* has the same color as *P. ampullacea*, but the structure of the shell tip is pointed. The species is native and does not cause harm to other species (Ng et al. 2020). *Pila scutata* is used as a bioindicator of water pollution (Prasetia et al. 2022). *Z. detrita* is a species with a small shell size, a blunt tip, and a brownish caramel color. The species' habitat is in the substrate of plants or mud. The temperature for survival are 20-38°C (Kalcheva et al. 2020). It can be used as accessories for bracelets, necklaces, etc. (Sundalian et al. 2022). *P. hammonis* is very difficult to find on the Bengawan Solo riverbanks because they likes lithophytic substrates in hard holes, such as concrete, on the banks of the river in humid conditions. The species live in the temperature of 20-38°C and they are often used to add nutrients to fish food (Makarchuk et al. 2020).

Invasive species of gastropods

As presented in Table 2, there were several gastropod species found in the upper Bengawan Solo River considered as invasive, including *T. granifera*, *S. testudinaria*, *F. ater*, *A. immaculata*, *P. canaliculata*, *S. riquetii*, *L. flammea*, *L. littorea*, *P. hammonis*, *V. glacialis*, *V. viviparus*, *V. intertextus*, *S. libertina*, *B. costula*, *Z. detrita*, and *M. tuberculata*. Some invasive species poses threat to native species, but some others are not (Kirk et al. 2020). The invasive gastropods originated from Southeast Asia, Japan, the American Continent, the European Continent, Middle East Asia, and the United Kingdom. Native gastropods are similar to those in other countries, including *S. testudinaria, F. javanica, S. punctata, S. denisoniensis, Perpolita harmonis, L. littorea, P. scutata, P. ampullacea*, and *C. chinensis* (Veeravechsukij et al. 2018; Sawada et al. 2020; Lailiyah et al. 2021; Nguyen et al. 2021; Gusna et al. 2022).

The spread of invasive alien species can harm native species when living in their new habitat due to competition for food (Veeravechsukij et al. 2018; Nguyen et al. 2021; Gusna et al. 2022), causing an imbalance in the ecosystem and affecting the numbers and types of benthic community structures (Raiba et al. 2022). *P. hammonis* is included as invasive species and prefers to live on plant stems (Sánchez et al. 2021). According to Yin et al. (2022), alien gastropods can produce eggs if they can adapt to their new habitat that supports their living, such as water quality, temperature, humidity, and turbidity. *T. granifera* and *F. ater* are invasive species originated from Africa and the Philippines and have some distribution in the Pacific Islands (Gusna et al. 2022). *T. granifera* and *S. testudinaria* easily reproduce by producing many eggs to be carried by ships or birds when looking a food, but *T. granifera* will more easily dominate in its new habitat (Yakovenko et al. 2018; Lentge-Maaß et al. 2021). *F. ater* differs from the other two species because it is difficult to adapt, and produced very few eggs (Dewi et al. 2022). *T. granifera* are dangerous because they on omnivorous species (Komatsu and Saeki 2022) which might act as the highest predators at trophic level (Aryzegovina et al. 2022), indirectly endangering other native species.

Pomacea canaliculata is considered as invasive (Qin et al. 2020). *Pomacea canaliculata* originated from South America, and was brought to Indonesia due to its benefits as a bioindicator (Qin et al. 2020). This species is considered invasive and can easily produce eggs, even though not as many as *T. granifera*; although, *P. canaliculata* is very difficult to find at some stations. *Semisulcospira* is a species native to Central Asia and is found in southern China and Japan and is considered as invasive although it do not harm other native species because it is a food source for fish (Sawada et al. 2020). This species can easily be found in 22.5°C waters with abundant foodstuffs such as plankton, detritus, and chemoautotrophic bacteria (Morita et al. 2024).

Melanoides tuberculata is an invasive which is easily found in various places where habitat conditions have a lot of algae resources (Ouedraogo et al. 2023). *Sulcospira testudinaria* is easy to find because it can produce many eggs, and the species easily adapts to the new environment (Du and Yang 2019). According to Wahyuningsih and Umam (2022), gastropod species can easily adapt because they tolerate polluted waters. *V. intertextus* is an invasive species (Arias et al. 2020) originated from the Asian continent and then moved to the American continent through sea transportation, humans, etc. (David et al. 2020). Some efforts that can be made against invasive alien species are mechanical, chemical, and biological controls (Syafei and Sudinno 2018). Therefore, if treatment efforts are not made and it indirectly enters Asia, this species can potentially endanger other native gastropods.

While there were several alien invasive species, there were native species of gastropods found in the upper Bengawan Solo River including *P. scutata*, *P. ampullacea*, *S. testudinaria*, *F. javanica*, *S. punctata*, *S. denisoniensis*, *C. chinensis* and *A. phoenix*. Research by Edgar et al. (2022) stated that *C. chinensis* is native species under the Viviparidae mollusca. *F. javanica* is a native gastropod with a small number that is difficult to find (Maldonado and Martín 2019). *Pila scutata* and *P. ampullacea* are native (Marwoto et al. 2020) which can produce hundreds of eggs laid in groups, stored above the water surface in moist soil, and protected by plant litters (Suartini and Sudatri 2021). *S. denisoniensis* and *S. punctata* are not considered harmful or invasive species (Willan and Kessner 2021). However, *S. punctata* was originally similar to invasive alien species such as *M. tuberculata* (Isnaingsih et al. 2021). Both species are often found in riverine areas with sandy conditions or small pebbles (Harding et al. 2019).

Diversity index

The Shannon-Wiener diversity index is shown in Figure 4. Shannon-Wiener diversity index shows the ecological stability of a habitat indicated by the species number found in a community; if the number of species in a community is high, it can be said that the habitat is in good condition (Ulmaula et al. 2016). Conversely, if the species diversity is low, it can be ascertained that the species occupying the habitat cannot live properly. There were 9 species at station 1 in Wonogiri with a Shannon index value of 1.66, while station 2 in Sukoharjo, there were 9 species with a Shannon index of 1.79, station 3 in Surakarta with 10 species and Shannon index of 2.08, station 4 in Karanganyar with 5 species and Shannon index of 1.39 and station 5 in Sragen with 12 species and Shannon index of 2.10.

The upper Bengawan Solo River has substrate characteristics of mostly fine sand and mud (Tyas and Widiyanto 2015) while gastropods mostly live in coarse sand or mud sediments. Most gastropods found along the river had several similarities, so the substrate occupied by these gastropods was almost the same. However, when the rainfall is high, and the water level increases, many gastropods attached to the riverbank are flooded, but most are still alive. The Shannon-Wiener diversity index can be used to compare difference in species diversity among sites (Putra et al. 2015). The high diversity index at station 5 in Sragen, with an index value of 2.10, is because this site was abundant in nutrients, had suitable substrates for various species, and suitable temperatures, so that many species can adapt well. Diversity index also indicates water quality in the habitat. This high diversity is also supported by data from BBWS (*Balai Besar Wilayah Sungai*) in November 2023, showing that the Sragen station produced a Dissolved Oxygen (DO) value of 6.3 mg/L and a BOD of 1.6 mg/L. That shows the dissolved oxygen is high and the BOD content is low, so the gastropod diversity is high. This follows Ayu et al. (2015) that the lower the BOD levels and the higher the dissolved oxygen levels in the water, the better for gastropod respiration, resulting in the higher the gastropod diversity. The higher the species diversity, the better the water quality, and vice versa (Prabandini et al. 2021), and the symbiosis created among species also affects the high diversity of species in a habitat (Muhammad 2020).

Meanwhile, the lowest value of the Shannon diversity index was at station 4 in Karanganyar with a value of 1.39. Only 5 species were found at this station, indicating that some species cannot adapt quickly or move to more suitable habitats, reducing biodiversity. Based on data from BBWS in November 2023, it was found that the Dissolved Oxygen (DO) value at Karanganyar station was 1 mg/L, and the BOD was 2.1 mg/L, which shows that the DO is low, but the BOD content is higher than the Sragen station, so the gastropod diversity is low. According to Farid et al. (2023), higher BOD content indicates a lack of dissolved oxygen in the water, which will impact the diversity of gastropods. In addition, the soil structure and substrate in Karanganyar are physically unsuitable for gastropods, namely dry and coarse sand, so only certain species can survive in this habitat.

The presence of gastropod species in a water body cannot be assumed that the high diversity of gastropod species in an area will indicate its water quality. The presence of gastropod species does not necessarily indicate that a water body has water quality above the standard quality (Nadaa et al. 2021). Other factors, including the composition of native and invasive species in a habitat eventually leads to invasive species dominating the habitat and reducing the diversity of native species (Partaya and Setiati 2022). In addition, there is a lack of vital resources such as water quality, food intake for gastropods, and unsuitable reproduction sites for the species (Lasari and Harahap 2022).

Dominance index

The dominance index describes a species' dominance over other species in an ecosystem community. The higher the dominance index value of a species, an ecosystem is dominated by certain species, vice versa if the dominance index value is low, the community is evenly composed by various species (Nahlunnisa et al. 2016). According to Ridwan et al. (2016), dominance is expressed as the species richness of a community and the balance of the number of individuals of each species found. The dominance index of ≤0.5 means that almost no species dominates (low), while the index of more than 0.5 and less than 1 means high dominance index. The dominance index in this study is included in the low category, suggesting that almost no species dominated at each observation station (Figure 4). Overall, the dominance index across all stations was 0.2 where at station 1 (Wonogiri) the index was 0.24, station 2 (Sukoharjo) was 0.21, station 3 (Surakarta) was 0.14, station 4 (Karanganyar) was 0.28, station 5 (Sragen) was 0.14.

Station 1 in Wonogiri had a sandy substrate. In addition to being easily carried by water currents and experiencing dryness when the low tide periods, gastropods will choose a habitat that is easy to use as a place to live due to the adaptability to stick to rocky substrates in tidal areas. Certain gastropod species can only achieve those survival abilities, which will affect dominance parameters (Beni et al. 2020). Station 2 composed with a lot of grass, causing gastropod diversity to be higher than that at stations 1 and 4 and the dominance at this station was also higher when compared to stations 3 and 5. This indicates that some gastropods eat grass, rice, and other weeds; hence, the amount of weed distribution around affects the intensity of gastropods found (Awang et al. 2023). The highest dominance value was found at station 4 in Karanganyar due to the presence of muddy substrate and a lot of grass, which are favorable by fewer gastropods (Abubakar et al. 2018).

Station 3 in Surakarta had a fine sandy substrate and was muddy. The dominance shown at station 3 was lower when compared to other stations and the diversity level is high. Similarly, station 5 had dominance index lower than other stations. According to Hulopi et al. (2022), the dominance index that is close to 0 and is included in the low category indicates that there is no dominance of certain species of gastropods or that the community is in a stable state. Station 5 had the highest diversity index and lowest dominance compared to other stations, except for station 3. This result indicates that Sragen has a good substrate, namely rocky, muddy sand, and grass, that can support the vegetation and breeding of gastropods (Parorrongan et al. 2018).

The main factors affecting the number of organisms, species diversity, and dominance include the destruction of natural habitats, such as land conversion, chemical and organic pollution, and climate change (Mardi et al. 2019). Therefore, compared to the other stations, station 5 in Sragen had the lowest dominance index along with station 3 due to the low organic content of the substrate, so only certain gastropods can survive. Stations 3 and 5 had a mixed substrate of sandy mud, allowing carnivorous, detritus-eating scavenger gastropods to be found. Meanwhile, herbivorous or algae-eating gastropods will likely be found very little along Bengawan Solo. Algae-eating gastropods can only be found in areas with rocky substrates (Gea et al. 2019). In addition, residential areas far from the river basin make this river able to maintain abiotic factors suitable for the life of biota, especially gastropods.

Figure 4 shows that stations with high Shannon-Wiener diversity index values tend to have lower Simpson's dominance index. For example, Stations 3 and 5 had high diversity values (2.08 and 2.15) but low dominance values (0.14 and 0.14), respectively. This indicates a high variety of species but low dominance of one or few particular species. Conversely, stations with low Shannon-Wiener diversity index values tend to have higher Simpson's dominance index values (Nahlunnisa et al. 2016). Stations 1, 2, and 4 had lower Shannon-Wiener index values (1.79, 1.66, and 1.39) but higher dominance values (0.21, 0.24, and 0.28). According to Partlova et al. (2020), the Shannon-Wiener index measures the total diversity of species, while Simpson's dominance index focuses on the dominance of a particular species. Thus, there is an inverse relationship between these two indices at the study stations; the higher diversity (Shannon-Wiener index), the lower dominance (Simpson index), and vice versa. Ashton and Macintosh (2002) explain that the high dominance of one species may indicate a stressful environment, while higher diversity indicates stable conditions in the ecosystem. Inter-species competition is among the most influential factors; therefore, a species dominating a particular environment can reduce overall diversity. Furthermore, the presence of invasive species can alter ecosystem dynamics, reducing diversity by displacing native species and increasing the dominance of certain species (Borden and Flory 2021)

Gastropods density

Gastropod density indicates the number of individuals living in a certain habitat, area, and time (Persulessy and Arini 2018). Irawan (2008) stated that the density value is a parameter of the quality of a habitat; a high-density value indicates that the habitat is very suitable for the life of organisms. This indicates that a large number of organisms can occupy the habitat. The density index is shown in Table 3 and Figure 4.

Table 3. Gastropod species density index in the upper Bengawan Solo River, Central Java, Indonesia

Species names	Stations				
	1	2	3	4	5
Tarebia granifera (Lamarck, 1816)	5.13	1.88	0.05	1.23	0.63
Pomacea canaliculata (Lamarck, 1822)	0.16	0.12	0.11	0.93	1.22
Semisulcospira libertina (A. Gould, 1859)	0.92	0.67		2.63	
Melanoides tuberculata (O.F. Muller, 1774)	1.36	0.56		0.92	0.31
Filopaludina javanica (Busch, 1844)	0.36	0.07	0.22		0.26
Sulcospira testudinaria (Busch, 1842)	3.87	1.11	0.43		0.97
Stenomelania punctata (Lamarck, 1822)		0.35			
Stenomelania denisoniensis (Brot, 1877)	0.27				
Viviparus intertextus (Say, 1829)	0.25				
Sermyla riquetii (Grateloup, 1840)	1.33				
Pila scutata (Mousson, 1848)			0.23		
Pila ampullacea (Linnaeus, 1758)		0.08			0.27
Faunus ater (Linnaeus, 1758)			0.6		
Limicolaria flammea (O.F. Muller 1774)			0.12		
Achatina immaculata (Lamarck, 1822)			0.1	0.25	0.08
Acavus phoenix (L. Pfeiffer, 1854)			0.3		
Segmentina nitida (Strom, 1765)			0.18		
Viviparus viviparus (Linnaeus, 1758)					1.46
Cipangopaludina chinensis (J.E.Gray, 1833)					0.05
Littorina litorea (Linnaeus, 1758)					0.26
Viviparus glacialis (S.V. Wood, 1872)					0.45
Zebrina detrita (O.F. Muller, 1774)					0.07
Brotia costula (Rafinesque, 1833)		0.4			
Total	13.65	5.24	2.34	5.96	6.25

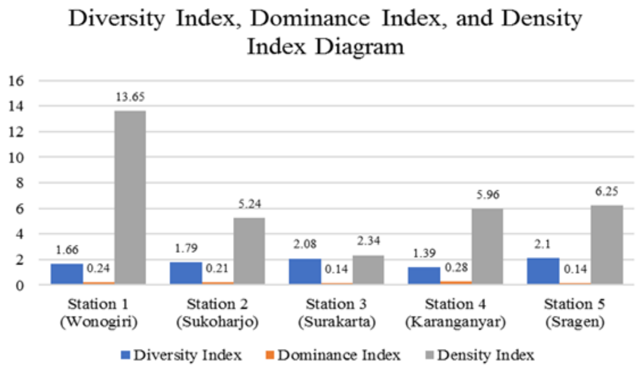

Figure 4. Diversity index, dominance index, and density index of gastropod species found in the upper Bengawan Solo River, Central Java, Indonesia

Species with the highest density at station 1 were *T. granifera* (5.13 ind./m^2), *S. testudinaria* (3.87 ind./m^2), *M. tuberculata* (1.36 ind./m^2) and *S. riquetii* (1.33 ind./m^2). Species with the highest density at station 2 were *T. granifera* (1.88 ind./m^2) and *S. testudinaria* (1.11 ind./m^2). The species with the highest density at station 3 was *F. ater* (0.6 ind./m^2). Species with the highest density at station 4 were *S. libertina* (2.63 ind./m^2) and *T. granifera* (1.23 ind./m^2). Species with the highest density at station 5 were *V. viviparus* (1.46 ind./m^2) and *P. canaliculata* (1.22 ind./m^2).

Table 3 shows that among high-density species are invasive alien species, namely *T. granifera, S. testudinaria, M. tuberculata, S. riquetii, S. libertina, F. ater, V. viviparus,* and *P. canaliculata.* The presence of invasive gastropods will pose a significant potential threat to the ecosystem. These invasive species accidentally enter and live outside their native range. The dominance of invasive alien species can pose a threat by disturbing the balance of ecological system and can lead to the loss of local species, so the existence of invasive alien species could threaten aquatic biodiversity in Bengawan Solo River (Sirza et al. 2020). The presence of invasive gastropod species in rivers will potentially threaten native gastropod species, destroy the ecosystem, and threaten public health as well as agriculture (Li et al. 2023). The spread of invasive alien species is one of the significant threats to the biodiversity of native aquatic fauna (Diagne et al. 2021). Invasive alien gastropods have high reproduction ability which threatening aquatic and terrestrial ecosystems (Jiang et al. 2022). Due to their high appetite, high reproductivity, and dispersal ability, invasive gastropods can alter nutrient balances and cause rapid changes in aquatic and terrestrial ecosystem communities. Wittenberg and Cock (2001) stated that invasive alien species also impose enormous costs on the fisheries sector besides threatening biodiversity. In addition, many invasive gastropods carry bacteria and parasites that, when handled by humans with bare hands or eaten, potentially pose a significant threat to human health (Mazza et al. 2014). Therefore, prioritizing monitoring and controlling invasive alien gastropods are necessary in the Upper Bengawan Solo River. Conservation strategies can be carried out to control invasive alien species, such as developing appropriate regulations and eradication methods appropriately (Purnama et al. 2022b).

Figure 4 shows that stations 1, 2, and 4 had lower diversity index values and higher dominance indices compared to the other two stations. Concurrently, there three stations had species with high-density values. The number of species found in these stations was relatively small compared to other two stations, resulting in the high dominance index, where the greater the density value, the greater the tendency of one species to dominate the population (Gea et al. 2019). Stations 3 and 5, with higher diversity index and lower dominance index, had more species found, and species with the highest density did not have a large gap with other species. According to Odum (1994), a community has high species diversity if the community is composed of many species with the same abundance. Conversely, if the community is composed of very few species, and if only a few species are dominant, then the diversity is low.

In conclusion, there were 23 species from 9 families of gastropods in the upper Bengawan Solo River including 16 invasive species and 7 native species. The diversity and dominance of species among the five stations differed due to differences in substrate types (such as sandy, muddy, or rocky) and abiotic factors. The diversity of gastropods found at all research stations was classified as moderate (1.39-2.10) while the dominance index was in the low category (0.14-0.28), indicating no dominant species. Factors that influence both indices include habitat diversity, environmental pressure, competition between species, the presence of invasive species, predator-prey interactions, diversity of nutrient sources, and land use and environmental management. Some invasive gastropod species such as *T. granifera, S. testudinaria, M. tuberculata, S. riquetii, S. libertina, F. ater, V. viviparus,* and *P. canaliculata* had high density compared to other species. The high density of invasive alien gastropods can pose a threat to the ecological integrity of aquatic ecosystem in the upper Bengawan Solo River and might lead to the loss of native species.

REFERENCES

Abubakar S, Kadir MA, Akbar N, Tahir I. 2018. Associations and microhabitat niches of gastropods in mangrove ecosystems on Sibu Island Oba Utara Sub-district Tidore City Islands of North Maluku Province. Jurnal Enggano 3 (1): 22-38. DOI: 10.31186/jenggano.3.1.22-38. [Indonesian]

Aida SN, Utomo AD, Anggraeni DP, Ditya YC, Wulandari TNM, Ali M, Caipang CMA, Suharman I. 2022. Distribution of fish species in relation water quality conditions in Bengawan Solo River, Central Java, Indonesia. Pol J Environ Stud 31 (6): 5549-5561. DOI: 10.15244/pjoes/15216 7.

Aini N, Hakim L, Retnaningdyah C. 2020. Evaluation of ecosystem services mangrove restoration area in South Malang. Intl J Sci Res Publ 10 (7): 849-854. DOI: 10.29322/IJSRP.10.07.2020.p10395.

Albarrán-Mélzer NC, Ruiz LJR, Benítez HA, Lagos ME. 2020. Can temperature shift morphological changes of invasive species? A morphometric approach on the shells of two tropical freshwater snail species. Hydrobiologia 847: 151-160. DOI: 10.1007/s10750-019-04078-z.

Apiraksena K, Namchote S, Komsuwan J, Dechraksa W, Tharapoom K, Veeravechsukij N, Glaubrecht M, Krailas D. 2020. Survey of *Stenomelania* Fischer 1885 (Cerithioidea, Thiaridae): The potential of trematode infections in a newly-recorded snail genus at the coast of Andaman Sea, South Thailand. Zoosyst Evol 96 (2): 807-819. DOI: 10.3897/zse.96.59448.

Arfiati D, Syahid N, Anwari Z, Aminin A, Kusriani K, Herawati EY, Puspitasari AW. 2021. The effect of water treatment models to reduce lead (Pb) level on freshwater snail *Filopaludina javanica*. Res J Life Sci 8 (2): 85-94. DOI: 10.21776/ub.rjls.2021.008.02.3.

Arias A, Fernández-Rodríguez I, Sánchez O, Borrell YJ. 2020. Integrative taxonomy reveals the occurrence of the Asian freshwater snail *Sinotaia* cf. *quadrata* in inland waters of SW Europe. Aquat Invasions 15 (4): 616-632. DOI: 10.3391/ai.2020.15.4.05.

Arumsari PL, Adharini RI. 2021. Structure and distribution of macrobenthos community in Code River, Yogyakarta, Indonesia. Indones J Limnol 2 (2): 21-27. DOI: 10.51264/inajl.v2i2.17.

Aryzegovina R, Aisyah S, Desmiati I. 2022. Analysis of gut and stomach contents to determine the food and feeding habit of betok fish (*Anabas testudineus*). Konservasi Hayati 18 (1): 9-21. DOI: 10.33369/hayati.v18i1.20699. [Indonesian]

Ashton EC, Macintosh DJ. 2002. Preliminary assessment of the plant diversity and community ecology of the Sematan mangrove forest, Sarawak, Malaysia. For Ecol Manag 166 (1-3): 111-129. DOI: 10.1016/S0378-1127(01)00673-9.

Awang SM, Lalupanda EM, Ina AT. 2023. Biodiversity gastropoda in Kandara rice fields Kambera District East Sumba Regency. Bio-Sains 2 (2): 57-61. DOI: 10.6084/m9.figshare.23564679. [Indonesian]

Ayu DM, Nugroho AS, Rahmawati RC. 2015. The diversity of gastropod as bio-indicator of contamination of leachate of Jatibarang dumping ground in Kreo River Semarang City. Seminar Nasional XII Pendidikan Biologi FKIP UNS 2015: 700-707. [Indonesian]

Bae MJ, Kim EJ, Park YS. 2021. Comparison of invasive apple snail (*Pomacea canaliculata*) behaviors in different water temperature gradients. Water 13: 1149. DOI: 10.3390/w13091149.

BBWS (*Kementerian PUPR Ditjen Sumber Daya Air BBWS Bengawan Solo*). 2023. Water Quality of Bengawan Solo River in 2023. Sistem Informasi Hidrologi BBWS Solo. https://hidrologi.bbws-bsolo.net/kualitasair. [Indonesian]

Beni, Zairion, Wardiatno Y. 2020. Biological aspect of double-spined rock lobster (*Panulirus penicillatus*) in Wonogiri Regency Waters, Central Java, Indonesia. IOP Conf Ser: Earth Environ Sci 420: 012006. DOI: 10.1088/1755-1315/420/1/012006.

Bohatá L, Patoka J. 2023. Invasion potential of ornamental terrestrial gastropods in Europe based on climate matching. Diversity 15 (2): 272. DOI: 10.3390/d15020272.

Borden JB, Flory SL. 2021. Urban evolution of invasive species. Front Ecol Environ 19 (3): 184-191. DOI: 10.1002/fee.2295.

Darmawan A, Sulardiono B, Haeruddin H. 2018. Analysis of water fertility based on phytoplankton abundance, nitrate and phosphate in the waters of the Bengawan Solo River, Surakarta City. Manag Aquat Resour J 7 (1): 1-8. DOI: 10.14710/marj.v7i1.22519. [Indonesian]

David AA, Pettit L, Edmund M. 2020. Resilience of a highly invasive freshwater gastropod, *Viviparus georgianus* (Caenogastropoda: Viviparidae), to CO_2-induced acidification. J Molluscan Stud 86 (3): 259-262. DOI: 10.1093/mollus/eyaa008.

David P, Thebault E, Anneville O, Duyck PF, Chapuis E, Loeuille N. 2017. Impacts of invasive species on food webs: A review of empirical data. Adv Ecol Res 56: 1-60. DOI: 10.1016/bs.aecr.2016.10.001.

Dewi E, Agustina R, Sarong MA, Yulianda F, Suhendrayatn S. 2022. Histopathological analysis of *Faunus ater* ovotestis in Bale and Reuleueng Rivers, Aceh Besar Regency, Aceh Province, Indonesia. Open Access Maced J Med Sci 10: 1273-1277. DOI: 10.3889/oamjms.2022.9878.

Diagne C, Leroy B, Vaissière A-C, Gozlan RE, Roiz D, Jarić I, Salles JM, Bradshaw CJA, Courchamp F. 2021. High and rising economic costs of biological invasions worldwide. Nature 592: 571-576. DOI: 10.1038/s41586-021-03405-6.

Du LN, Yang JX. 2019. A review of *Sulcospira* (Gastropoda: Pachychilidae) from China, with description of two new species. Molluscan Res 39 (3): 241-252. DOI: 10.1080/13235818.2019.1572848.

Edgar MR, Hanington PC, Lu R, Proctor H, Zurawell R, Kimmel N, Poesch MS. 2022. The first documented occurrence and life history characteristics of the Chinese mystery snail, *Cipangopaludina chinensis* (Gray, 1834) (Mollusca: Viviparidae), in Alberta, Canada. Bioinvasions Rec 11 (2): 449-460. DOI: 10.3391/bir.2022.11.2.18.

Ehigie AF, Okonji RE, Ojeniyi FD, Jesulade MO, Ehigie LO. 2020. Physicochemical properties of 3-Mercaptopyruvate Sulfurtransferase: A cyanide detoxifying enzyme from the hemolymph of *Limicolaria flammae* (garden snail). Pan Afr J Life Sci 4 (2): 68-76. DOI: 10.36108/pajols/0202/40(0250).

Envin BJA, Ekissi ESG, Sea TB, Rougbo NP, Kouamé LP. 2020. Effects (in vivo) of the nutritional potential of snail *Limicolaria flammea* (Müller) meat on wistar rats. GSC Biol Pharm Sci 11 (2): 71-79. DOI: 10.30574/gscbps.2020.11.2.0108.

Farid A, Desyderia FT, Arisandi A, Triajie H. 2023. Gastropod abundance as a bioindicator of water quality in river flow in East Gili Village, Kamal District, Bangkalan Madura Regency. J Fish Mar Res 7 (2): 107-118. DOI: 10.21776/ub.jfmr.2022.007.02.12. [Indonesian]

Ferisandi R, Dharmawibawa ID, Safnowandi S. 2018. Diversity of gastropod species in Jangkok River, Mataram City as a basis for preparing ecology practicum instructions. Bioscientist: Jurnal Ilmiah Biologi 6 (1): 80-90. DOI: 10.33394/bioscientist.v6i1.2368. [Indonesian]

Fernanda A. 2021. Diversity of freshwater gastropods in the Pancur River Resort of Alas Purwo National Park and its utilization as a popular scientific book. [Thesis]. Universitas Jember, Jember. [Indonesian]

Firmansyah IA, Mileniawati JP, Rahayu MN. 2020. Bengawan Solo and Musi Rivers in maritime history review. Riwayat: Educ J Hist Humanities 3 (2): 7-13. [Indonesian]

Gea BP, Rahayu B, Faizatuluhmi S, Komala R. 2019. Mollusc community structure and water quality in Carita Special Purpose Forest Area, Pandeglang, Banten. Biotropika 7 (1): 21-28. DOI: 10.21776/ub.biotropika.2019.007.01.03. [Indonesian]

Gurumayum SD. 2023. A preliminary report on freshwater mollusca of Arunachal Pradesh, Northeast India and first report of an exotic invasive species *Physella acuta* (Draparnaud, 1805) from the state. Rec Zool Surv India 123 (1): 109-115. DOI: 10.26515/rzsi/v123/i1/2023/162219.

Gusna GM, Nurdin J, Mursyid A, Putra W, Aryzegovina R, Junialdi R. 2022. Analysis of organic pollution of Masang Kecil River in West Pasaman District based on macrozoobenthos community and biological indices. Konservasi Hayati 18 (2): 69-79. DOI: 10.33369/hayati.v18i2.23962. [Indonesian]

Haqqi MRA, Sholichah DM, Armando MF, Sani MF, Aprianto MK, Dewangga A, Yap CK, Dadiono MS, Setyawan AD. 2024. Species diversity and the spread of invasive fish in the Upper Bengawan Solo River, Central Java, Indonesia. Biodiversitas 25 (10): 4000-4010. DOI: 10.13057/biodiv/d251060

Harahap P. 2020. Use of some plant powders to control the carp *Pomacea canaliculata* Lamarck (Mollusca: Ampullariidae) in rice plants in the Greenhouse. Fruitset Sains : Jurnal Pertanian Agroteknologi 8 (2): 51-57. [Indonesian]

Harding S, Rodriguez D, Jackson J, Huffman D. 2019. Genetic and morphological variation is associated with differences in cold-water tolerance and geographic expansion among invasive snails (*Melanoides tuberculata*) in central Texas. BioRxiv 1: 1-41. DOI: 10.1101/2019.12.20.884866.

Hartati H, Azmin N, Nasir M, Yulianti M. 2022. Inventarisasi keanekaragaman gastropoda di kawasan mangrove Desa Wilamaci Kecamatan Monta Kabupaten Bima. Oryza Jurnal Pendidikan Biologi 11 (1): 1-6. [Indonesian]

Hasan V, Andraini NE, Isroni W, Sari LA, Nafisyah AL, Dewi NN, Putri DNA, Prasasti TAB, Ramadhani AA, Daniel K, South J, Vieira LO, Ottoni FP, Maftuch, Faqih AR, Wirabuana PYAP, Tamam MB, Valen FS. 2023. Fish diversity of the Bengawan Solo River estuary, East Java, Indonesia. Biodiversitas 24 (4): 2207-2216. DOI: 10.13057/biodiv/d240433.

Hertika AMS, Arfiati D, Lusiana ED, Putra RBDS. 2023. Performance of metallothionein biomarker from *Sulcospira testudinaria* to assess heavy metal pollution in the Brantas River Watershed, Indonesia. J Ecol Eng 24 (3): 276-286. DOI: 10.12911/22998993/157470.

Hulopi M, Queljoe KMd, Uneputty PA. 2022. Diversity of gastropods at mangrove ecosystems on Passo Village District Baguala Ambon City. Jurnal TRITON 18 (2): 121-132. DOI: 10.30598/TRITONvol18issue2page121-132. [Indonesian]

Irawan I. 2008. Community structure of molluscs (gastropoda and bivalvia) and their distribution in Burung Island and Pulau Tikus, Pari

Island Cluster, Kepulauan Seribu. [Thesis]. Institut Pertanian Bogor, Bogor. [Indonesian]
Isnaingsih NR, Marwoto RM, Alfiah A, Prihandini R, Santoso PH. 2021. Studies on morphology, ontogeny and reproductive strategies in *Melanoides tuberculata* (Müller, 1774) and *Stenomelania punctata* (Lamarck, 1822) (Gastropoda: Cerithioidea: Thiaridae). Jurnal Ilmu-Ilmu Hayati 20 (2): 171-180. DOI: 10.14203/beritabiologiv20i1.3991. [Indonesian]
Jiang X, Zheng P, Soto I, Haubrock PJ, Chen J, Ji L. 2022. Global economic costs and knowledge gaps of invasive gastropods. Ecol Indic 145: 109614. DOI: 10.1016/j.ecolind.2022.109614.
Kalcheva S, Georgiev DM, Yankov Y. 2020. Morphometric studies of Protostrongylidae's third stage larvae (Nematoda: Protostrongylidae) found in *Helicella obvia* in the pastures of Central South Bulgaria. Bulgarian J Agric Sci 26 (Suppl 1): 133-140.
Kannan A, Rao SR, Ratnayeke S, Yow YY. 2020. The efficiency of universal mitochondrial DNA barcodes for species discrimination of *Pomacea canaliculata* and *Pomacea maculata*. PeerJ 8: e8755. DOI: 10.7717/peerj.8755.
Kingsbury SE, McAlpine DF, Cheng Y, Parker E, Campbell LM. 2020. A review of the non-indigenous Chinese mystery snail, *Cipangopaludina chinensis* (Viviparidae), in North America, with emphasis on occurrence in Canada and the potential impact on indigenous aquatic species. Environ Rev 29 (2): 182-200. DOI: 10.1139/er-2020-0064.
Kirk N, Kannemeyer R, Greenaway A, MacDonald E, Stronge D. 2020. Understanding attitudes on new technologies to manage invasive species. Pac Conserv Biol 26 (1): 35-44. DOI: 10.1071/PC18080.
Komatsu W, Saeki I. 2022. Feeding habits of the exotic invasive slug *Limax maximus*: A basis for risk assessment of herbivory on forest and agricultural ecosystems. Manag Biol Invasion 13 (4): 644-658. DOI: 10.3391/mbi.2022.13.4.04.
Krebs CJ. 1989. Ecologycal Methodology. Harper Collins Publisher, Inc., New York.
Kurniawati MA, Prayogo NA, Hidayati NV. 2023. Macrozoobenthos as bioindicators of water quality in Tajum River, Banyumas District, Central Java. Jurnal Ilmu Perikanan dan Kelautan 5 (2): 237-251. DOI: 10.36526/jl.v5i2.2791. [Indonesian]
Lailiyah S, Arfiati D, Hertika AMS, Arum NDK, Noviya CB. 2021. The effectiveness of *Filopaludina javanica* and *Sulcospira testudinaria* in reducing organic matter in catfish (*Clarias* sp.) aquaculture wastewater. Jurnal Ilmiah Perikanan dan Kelautan 13 (1): 116-123. DOI: 10.20473/jipk.v13i1.14725.
Lasari R, Harahap A. 2022. Composition and abundance of molluscs (gastropods and bivalves). BIOEDUSAINS: Jurnal Pendidikan Biologi dan Sains 5 (1): 279-285. DOI: 10.31539/bioedusains.v5i1.3521. [Indonesian]
Lentge-Maaß N, Neiber MT, Gimnich F, Glaubrecht M. 2021. Evolutionary systematics of the viviparous gastropod Sermyla (Gastropoda: Cerithioidea: Thiaridae), with the description of a new species. Zool J Linn Soc 192 (3): 736-762. DOI: 10.1093/zoolinnean/zlaa120.
Li P, Hong J, Yuan Z, Huang Y, Wu M, Ding T, Wu Z, Sun X, Lin D. 2023. Gut microbiota in parasite-transmitting gastropods. Infect Dis Poverty 12 (1): 105. DOI: 10.1186/s40249-023-01159-z.
Mainisa. 2019. The effect of giving various types of snails on growth and survival of pangasius catfish (*Pangasius pangasius*). Acta Aquatica: Aquat Sci J 6 (2): 76-79. DOI: 10.29103/aa.v6i2.1582. [Indonesian]
Majdi N, de Necker L, Fourie H, Loggenberg A, Netherlands EC, Bunte-Tschikin J, Traunspurger W, du Preez GC. 2022. Diversity and distribution of benthic invertebrates dwelling rivers of the Kruger National Park, South Africa. Koedoe 64 (1): a1702. DOI: 10.4102/koedoe.v64i1.1702.
Makarchuk DE, Yamskikh GY, Lebedeva NV, Brungardt VO, Bochka VV. 2020. Late Holocene malacofauna-based paleoenvironmental reconstruction for the Bazaikha River and Tartat River valleys (Krasnoyark Depression, Central Siberia). IOP Conf Ser: Earth Environ Sci 438: 012015. DOI: 10.1088/1755-1315/438/1/012015.
Maldonado MA, Martin PR. 2019. Dealing with a hyper-successful neighbor: Effects of the invasive apple snail *Pomacea canaliculata* on exotic and native snails in South America. Curr Zool 65 (3): 225-235. DOI: 10.1093/cz/zoy060.
Mardi M, Anwari S, Burhanuddin. 2019. Diversity of gastropod species in mangrove forest areas in Setapuk Besar Village, Singkawang City. Jurnal Hutan Lestari 7 (1): 379-389. DOI: 10.26418/jhl.v7i1.32090. [Indonesian]
Marwoto RM, Heryanto H, Joshi RC. 2020. The invasive apple snail *Pomacea canaliculata* in Indonesia: A case study in Lake Rawa Pening, Central Java. BIO Web Conf 19 (5): 00014. DOI: 10.1051/bioconf/20201900014.
Mazza G, Tricarico E, Genovesi P, Gherardi F. 2014. Biological invaders are threats to human health: An overview. Ethol Ecol Evol 26 (2-3): 112-129. DOI: 10.1080/03949370.2013.863225.
Moisez E, Spilmont N, Seuront L. 2020. Microhabitats choice in intertidal gastropods is species, temperature, and habitat-specific. J Therm Biol 94: 102785. DOI: 10.1016/j.jtherbio.2020.102785.
Morita K, Saito T, Uechi T, Sawada N, Miura O. 2024. Out of the ancient lake: Multiple riverine colonizations and diversification of the freshwater snails in the genus *Semisulcospira* around Lake Biwa. Mol Phylogenet Evol 191: 107987. DOI: 10.1016/j.ympev.2023.107987.
Mudjib CM, Lasminto U. 2013. Study of sediment transport of Pelangwot-Sedayu Lawas Sudetan of Bengawan Solo River. Jurnal Teknik Pomits 2 (3): 253-258. DOI: 10.12962/j23373539.v2i3.5236. [Indonesian]
Muhammad RS. 2020. Gastropod community structure in the upper Bedadung River, Jember District. [Undergraduate Thesis]. Universitas Jember, Jember. [Indonesian]
Mujiono N, Afriansyah, Putera AKS, Atmowidi T, Priawandiputra W. 2019. Diversity and composition of freshwater snails (Mollusca: Gastropoda) in several sites in Bogor and Sukabumi Districts. LIMNOTEK Perairan Darat Tropis di Indonesia 26 (2): 65-76. DOI: 10.14203/limnotek.v26i2.257.
Nadaa MS, Taufiq-Spj N, Redjeki S. 2021. Condition of macrozoobenthos (Gastropoda and Bivalvia) in mangrove ecosystem, Pari Island, Kepulauan Seribu, Jakarta. Buletin Oseanografi Marina 10 (1): 33-41. DOI: 10.14710/buloma.v10i1.26095. [Indonesian]
Nahlunnisa H, Zuhud EAM, Santosa Y. 2016. The diversity of plant species in high conservation value area of oil palm plantation in Riau Province. Media Konservasi 21 (1): 91-98. DOI: 10.29244/medkon.21.1.91-98. [Indonesian]
Negus P, J Marshall JC, Steward AL, McGregor GB, O'Connor R. 2021. The unique aquatic ecosystem of Talaroo Hot Springs. North Qld Nat 51: 67-86.
Ng TH, 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. J Mollusc Stud 86 (4): 290-305. DOI: 10.1093/mollus/eyaa015.
Nguyen HM, Van HH, Ho LT, Tatonova YV, Madsen H. 2021. Are *Melanoides tuberculata* and *Tarebia granifera* (Gastropoda, Thiaridae), suitable first intermediate hosts of *Clonorchis sinensis in* Vietnam?. PLoS Negl Trop Dis 15 (1): e0009093. DOI: 10.1371/journal.pntd.0009093.
Noorshilawati AA, Nur Suraya A, Siti Rossiyah S. 2020. Molluscicidal activity of *Ipomoea batatas* leaf extracts against *Pomacea canaliculata* (golden apple snail). Food Res 4 (Suppl. 5): 131-137. DOI: 10.26656/fr.2017.4(S5).003.
Nugroho BS, Wahyuni D, Asri A, Mustafa U. 2023. Effect of calcination temperature on the powder of freshwater snail shells (*Sulcospira testudinaria*) properties. Positron 13 (2): 158-165. DOI: 10.26418/positron.v13i2.70055.
Nurlina N, Harahap A. 2023. Studi spesies Gastropoda di perairan Sungai Berumun. BIOEDUSAINS: Jurnal Pendidikan Biologi dan Sains 6 (1): 248-255. DOI: 10.31539/bioedusains.v6i1.5499. [Indonesian]
Odum EP. 1994. Fundamentals of Ecology. Third Edition. Translation: Samingan T. Universitas Gadjah Mada Press, Yogyakarta. [Indonesian]
Oktavia, Warsidah, Safitri I, Sofiana MSJ, Apriansyah, Nurrahman YA. 2022. Nutritional value of gastropod *Cassidula* from the mangrove area of Desa Bakau, Sambas Regency, West Kalimantan. Jurnal Biologi Tropis 23 (1): 124-132. DOI: 10.29303/jbt.v23i1.4511.
Ouedraogo I, Kpoda NW, Oueda A, Bance V, Mano K, Kabre GB. 2023. Establishment of an invasive snail *Melanoides tuberculata* (Müller, 1774) in a Sahelian urban reservoir in Ouagadougou, Burkina Faso. BioInvasions Rec 12 (3): 797-808. DOI: 10.3391/bir.2023.12.3.15.
Parorrongan JR, Zahida F, Yuda IP. 2018. Diversity and abundance of gastropods at Seger Beach, Central Lombok. Biota 3 (2): 79-86. DOI: 10.24002/biota.v3i2.1896. [Indonesian]
Partaya P, Setiati N. 2022. Gastropod species diversity In Rawapening, Semarang District, Central Java. Prosiding Seminar Nasional Biologi. Universitas Negeri Semarang 10: 290-294. [Indonesian]

Partlova P, Vachal J, Dobrovic J, Tabor J. 2020. Use of the Shannon Wiener Index to measure lag diversity, a major player in regional rural development. Pol J Manag Stud 22 (1): 385-400. DOI: 10.17512/pjms.2020.22.1.25.

Persulessy M, Arini I. 2018. Keanekaragaman jenis dan kepadatan gastropoda di berbagai substrat berkarang di perairan Pantai Tihunitu Kecamatan Pulau Haruku Kabupaten Maluku Tengah. BIOPENDIX: Jurnal Biologi, Pendidikan dan Terapan5 (1): 45-52. DOI: 10.30598/biopendixvol5issue1page45-52. [Indonesian]

Prabandini FA, Rudiyanti S, Taufani WT. 2021. Analisis kelimpahan dan keanekaragaman Gastropoda sebagai indikator kualitas perairan di Rawa Pening. Pena Akuatika: Jurnal Ilmiah Perikanan dan Kelautan 20 (1): 93-101. DOI: 10.31941/penaakuatika.v20i1.1267. [Indonesian]

Pramono CL, Alyodya DA, Restuti EJ, Meilani F, Sholiqin M, Yap CK, Setyawan AD. 2024. Invasive and non-invasive macro aquatic plants in the Upper Bengawan Solo River, Indonesia. Intl J Bonorowo Wetlands 14 (1): 37-48. DOI: 10.13057/bonorowo/w140105.

Prasetia AA, Suwarsih, Sukma RN, Joesidawati MI, Spanton M PI. 2022. Keanekaragaman dan keterkaitan moluska pada ekosistem mangrove di Kecamatan Palang Kabupaten Tuban. Manfish J 2 (2) : 92-103. DOI: 10.31573/manfish.v2i2.381. [Indonesian]

Preece RC, Meijer T, Penkman KEH, Demarchi B, Mayhew DF, Parfitt SA. 2020. Corrigendum to “The palaeontology and dating of the ‘Weybourne Crag’, an important marker horizon in the Early Pleistocene of the southern North Sea basin. Quat Sci Rev 236: 106437. DOI: 10.1016/j.quascirev.2020.106437.

Priawandiputra W, Huda MIN, Kardinan AK, Prawasti TS. 2020. Morphometric characteristics and heavy metal bioaccumulation in edible freshwater gastropod (*Filopaludina javanica*). IOP Conf Ser: Earth Environ Sci 457: 012005. DOI: 10.1088/1755-1315/457/1/012005.

Purnama M, Salwiyah S, Nadia LOAR. 2022a. Diversity of freshwater gastropod in North Konawe Regency, Southeast Sulawesi. Jurnal Perikanan 12 (3): 365-377. DOI: 10.29303/jp.v12i3.334. [Indonesian]

Purnama MF, Sirza LOMJ, Sari SF, Salwiyah, Haslianti, Abdullah, Suwarjoyowirayatno, Findra MN, Nurhikma, Agriansyah A, Hidayat H, Syukur, Anwar K. 2022b. Diversity report of freshwater gastropods in Buton Island, Indonesia. Biodiversitas 23 (4): 1938-1949. DOI: 10.13057/biodiv/d230428.

Puspitasari E, Rosida DF, Putra AYT, Priyanto AD. 2022. Physicochemical properties of apple snail protein hydrolysate (*Pila ampullacea*) and its potential as flavor enhancer. Intl J Food Agric Nat Resour 3 (1): 27-32. DOI: 10.46676/ij-fanres.v3i1.74.

Putra DS, Irawan H, Zulfikar A. 2015. Gastropod diversity in the littoral waters of Pengujan Island, Bintan District. [Thesis]. Universitas Maritim Raja Ali Haji, Tanjung Pinang. [Indonesian]

Qin Z, Yang M, Zhang JE, Deng Z. 2020. Effects of salinity on survival, growth and reproduction of the invasive aquatic snail *Pomacea canaliculata* (Gastropoda: Ampullariidae). Hydrobiologia 847: 3103-3114. DOI: 10.1007/s10750-020-04320-z.

Raiba R, Ishak E, Permatahati YI. 2022. Intertidal epifauna gastropod community structureon the coast of Lampanairi Village, Batauga District, South Buton Regency. Jurnal Sains dan Inovasi Perikanan 6 (2): 87-102. DOI: 10.33772/jsipi.v6i2.17. [Indonesian]

Ridwan M, Fathoni R, Fatihah I, Pangestu DA. 2016. Community structure of macrozoobenthos in four rivers and estuaries in Pulau Dua Nature Conservation, Serang, Banten. Al-Kauniyah Jurnal Biologi 9 (1): 57-65. DOI: 10.15408/kauniyah.v9i1.3256. [Indonesian]

Rodrigo K, Manamendra-Arachchi K. 2020. Reconsidering the palaeo-environmental reconstruction of the wet zone of Sri Lanka: A zooarchaeological perspective. Intl J Environ Ecol Eng 14 (10): 284-294. DOI: 10.5281/ZENODO.4126896.

Salvador RB. 2022. Phylogenetic position of African punctoid snails (Stylommatophora, Punctoidea, Trachycystinae). Taxonomy 2 (2): 227-235. DOI: 10.3390/taxonomy2020017.

Salwiyah, Purnama MF, Syukur. 2022. Ecological index of freshwater gastropods in Kolaka District, Southeast Sulawesi, Indonesia. Biodiversitas 23 (6): 3031-3041. DOI: 10.13057/biodiv/d230630.

Sánchez O, Robla J, Arias A. 2021. Annotated and updated checklist of land and freshwater molluscs from Asturias (Northern Spain) with emphasis on parasite transmitters and exotic species. Diversity 13 (9): 415. DOI: 10.3390/d13090415.

Sano K, Fukuzono T, Yokoyama T, Chiba Y, Kato J. 2022. Breeding and conservation of *Luciola ruciate* Motschulsky, 1854 (Coleoptera: Lampyridae) larvae in forests near chemical factories. SN Appl Sci 4: 307. DOI: 10.1007/s42452-022-05196-5.

Sawada N, Toyohara H, Miyai T, Nakano T. 2020. Further records of introduced *Semisulcospira* snails in Japan (Mollusca, Gastropoda): Implications for these snails' correct morphological identification. BioInvasions Rec 9 (2): 310-319. DOI: 10.3391/bir.2020.9.2.16.

Sirza LJ, Purnama MF, Anwar K, Salwiyah, Abdullah. 2020. Invasive status of *Tarebia granifera* based on density of population in river of Gunung Sejuk Village, South Buton Regency. Aquasains 9 (1): 875-880. DOI: 10.23960/aqs.v9i1.p875-880.

Siswansyah RPP, Kuntjoro S. 2023. Correlation type of gastropods and the parameters of physical & chemical of water in the Mangetan River Canal of Kraton Village Sidoarjo. LenteraBio: Biological Scientific Period 12 (3): 371-380. DOI: 10.26740/lenterabio.v13n1. [Indonesian]

Suartini NM, Sudarti NW. 2021. Density, morphology and egg clusters of *Pila scutata* snails at rice fields area in Peringsari Village, Bali. KnE Life Sci 2022: 435-443. DOI: 10.18502/kls.v7i3.11150.

Sundalian M, Husein SG, Putri NKD. 2022. Review: Analysis and benefit of shells content of freshwater and land snails from gastropods class. Biointerface Res Appl Chem 12 (1): 508-517. DOI: 10.33263/BRIAC121.508517.

Syafei LS, Sudinno D. 2018. Invasive alien fish, a challenge to sustainable aquatic biodiversity. Jurnal Penyuluhan Perikanan dan Kelautan 12 (3): 145-161. DOI: 10.33378/jppik.v12i3.106. [Indonesian]

Tyas MW, Widiyanto J. 2015. Identification of gastropods in Gandong tributary sub basin, Kerik Village, Takeran. Florea 2 (2): 52-57. DOI: 10.25273/florea.v2i2.416. [Indonesian]

Ulmaula Z, Purnawan S, Sarong MA. 2016. Diversity of gastropods and bivalves based on sediment characteristics of the intertidal area of Ujong Pancu Beach, Peukan Bada Sub-district, Aceh Besar District. Jurnal Ilmiah Mahasiswa Kelautan dan Perikanan Unsyiah 1 (1): 124-134. [Indonesian]

Uribe JE, Colgan D, Castro LR, Kano Y, Zardoya R. 2016. Phylogenetic relationships among superfamilies of Neritimorpha (Mollusca: Gastropoda). Mol Phylogenet Evol 104: 21-31. DOI: 10.1016/j.ympev.2016.07.021.

Utomo AD, Ridho MR, Saleh E, Putranto D. 2017. Pollution in the Bengawan Solo River between Solo and Sragen, Central Java. BAWAL Widya Riset Perikanan Tangkap 3 (1): 25-32. DOI: 10.15578/bawal.3.1.2010.25-32. [Indonesian]

Veeravechsukij N, Krailas D, Namchote S, Wiggering B, Neiber MT, Glaubrecht M. 2018. Molecular phylogeography and reproductive biology of the freshwater snail *Tarebia granifera* in Thailand and Timor (Cerithioidea, Thiaridae): Morphological disparity versus genetic diversity. Zoosyst Evol 94 (2): 461-493. DOI: 10.3897/zse.94.28981.

Wahyuningsih E, Umam K. 2022. Gastropod diversity in Logawa River, Banyumas. Jurnal Binomial 5 (1): 81-94. DOI: 10.46918/bn.v5i1.1244. [Indonesian]

Wang X, Tang Y, Li Z, Wu Q, Qiao X, Wan F, Qian W, Liu C. 2023. Investigation of immune responses in giant African snail, *Achatina immaculata*, against a two-round lipopolysaccharide challenge. Intl J Mol Sci 24 (15): 12191. DOI: 10.3390/ ijms241512191.

Wei M, Mao W, Wenqing W, Yi L, Liuqing L, Chaoyi T. 2018. Biodiversity of mangrove mollusks in the west coast of Hainan Island, China. Biodiv Sci 26 (7): 707-716. DOI: 10.17520/biods.2018104.

Willan RC, Kessner V. 2021. A conspectus of the freshwater molluscs of the Daly River catchment, Northern Territory. North Territ Nat 30: 108-137. DOI: 10.5962/p.374216.

Wittenberg R, Cock MJW. 2001. Invasive alien species: A toolkit of best prevention and management practices. Publication of GISP. CAB International. DOI: 10.1079/9780851995694.0000.

Yakovenko V, Fedonenko O, Klimenko O, Petrovsky O. 2018. Biological control of the invasive snail species *Melanoides tuberculata* and *Tarebia granifera* in Zaporizka Nuclear Power Plant cooling pond. Ukr J Ecol 8 (1): 975-982. DOI: 10.15421/2017_301.

Yin N, Zhao S, Huang XC, Ouyang S, Wu XP. 2022. Complete mitochondrial genome of the freshwater snail *Tarebia granifera* (Lamarck, 1816) (Gastropoda: Cerithioidea: Thiaridae). Mitochondrial DNA B Resour 7 (1): 259-261. DOI: 10.1080/23802359.2022.2026832.