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Freshwater gastropod community in South Konawe District, Southeast Sulawesi, Indonesia

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Abstract. *Oetama D, Purnama MF. 2022. Freshwater gastropod community in South Konawe District, Southeast Sulawesi, Indonesia. Biodiversitas 23: 3364-3372.* The freshwater gastropod population in South Konawe District, Southeast Sulawesi, Indonesia, consists of aquatic and terrestrial snail communities. This resource (gastropod) is an ecological and economic potential that needs to be maintained and utilized optimally and sustainably. This research was conducted in April-July 2021 and aimed to determine the ecological index of the inland gastropod community in the South Konawe District. The sampling location was determined qualitatively using the purposive sampling method and a simple random sampling technique (Quantitative based). Gastropod samples were collected manually (hand picking) with a paralon pipe (3.5 inches), Sieve (1 mm), and Gloves. The total gastropods obtained at 33 sampling locations in this district were 2635 individuals. The inland gastropods comprised 19 genera and 33 species spread over 9 families, namely Achantinidae, Ampullariidae, Ariophantidae, Lymnaeidae, Neritidae, Pachychilidae, Planorbidae, Thiaridae, and Viviparidae. The average abundance of gastropods reached 79.85 ind./m^2 and the abundance of gastropod species ranged from 0.58-13.48 ind./m^2. Overall, the analysis of gastropod ecology index showed a stable condition, where the diversity of gastropod species was categorized as high (H'= 3.03), moderate evenness (E= 0.87), and high species richness (R= 4.06). There were no dominant species (C= 0.08) and the gastropod distribution showed a clustered pattern (Ip= 0.02). These ecological index values indicated that the gastropod community in the inland waters of South Konawe District was in a stable condition. Although the gastropod community in the inland waters of the South Konawe District simultaneously has the same area as the invasive gastropod from the family Thiaridae, namely *Melanoides tuberculata* (O.F.Müller, 1774) and *Tarebia granifera* (Lamarck, 1816).

Keywords: Biodiversity, ecological index, inland waters, invasive species, polymorphism, snail/slug

INTRODUCTION

South Konawe District, Southeast Sulawesi, Indonesia, has several large rivers (Lapoa, Laeya, and Roraya Rivers), which have great potential for developing the inland fisheries sector (BPS Sultra 2019; BPS Konawe Selatan 2021). One important land-based freshwater fishery resource in this district is the gastropod commodity (Purnama et al. 2019). The name gastropod comes from the ancient Greek words *"gastros,"* which means stomach, and *"podos,"* which means feet. This is because these animals move using the leg muscles located in the abdomen to move (Cuvier 1795). Most gastropods are shelled animals, and some do not have a shell. This group of snails (without shells) is generally called a slug. They generally have a single shell twisted in a spiral from the embryonic stage with various colors and shapes (Harminto 2003). The inland gastropod community in this area is very diverse in terms of type and shape (polymorphism). Study by Purnama et al. (2019) indicated that there are ± 30 species of freshwater gastropods (snails) with a wide range of polymorphic morphologies. Some of them are used as consumption materials, such as Boiku (*Bellamya javanica*) and *Filopaludina javanica*), Kowoe (*Pila ampullacea*), and Kasoso (*Melanoides tuberculata*) from the family Thiaridae (Sari et al. 2016; Haslianti et al. 2017; Purnama et al. 2019). Other species are a unified component of the ecosystem (biotic) that have ecological roles in the homeostatic system of inland waters. The presence of gastropods affects the balance of ecological niches in interspecific and intraspecific settings, indicating they not only have economic value but also play an important role in supporting the biota ecosystem. There are no data available on the ecological index of freshwater gastropods in South Konawe District, therefore, empirical research is needed as the first step to support the sustainability of the freshwater gastropod community in this district. The study can reveal the potential of freshwater gastropods and maximize their utilization. Furthermore, it will provide a recommendation for the sustainable management of gastropod resources as well as an indicator of environmental health or ecosystem balance. In addition, this study also directly becomes a medium for monitoring the presence of invasive species (IAS), whose presence can threaten the sustainability of local or endemic species (indigenous species) in this area because according to previous research by Purnama et al. (2019; 2020) that the gastropod community in the South Konawe District occupies a habitat which is also an existing area of invasive alien species from the family Thiaridae such as *Tarebia granifera* and *M. tuberculata*. So this research must be carried out as a first step in analyzing its ecological influence on the inland waters of the South Konawe District. This study aimed to determine the community structure of freshwater gastropods in the South Konawe District, especially their abundance, diversity, uniformity, species richness, dominance, and distribution patterns.

MATERIALS AND METHODS

This research was conducted for 4 months (April-July 2021) in South Konawe District, Southeast Sulawesi, Indonesia. The sampling location was determined qualitatively using the purposive sampling method (Figure 1). According to Arikunto (2006), purposive sampling is a technique that is not based on random, regional, or strata but on considerations that focus on predetermined goals or certain considerations such as characteristics previously known population or traits. As in this study, the research station was determined based on the main research target, which was to get as many gastropod samples as possible to obtain an overview of the gastropod ecological index in the South Konawe District so that a special consideration in the study was "land-water areas that have gastropod commodities." In contrast, the sampling of gastropods used quantitative methods with a simple random sampling technique at predetermined sampling points. Gastropod samples were collected manually without special fishing gear using a paralon pipe (3.5 inches), Sieve (1 mm), Gloves, and a square transect (plot) measuring 1 m^2. The sampling process for gastropod communities in all study sites (Table 1) was carried out for ± 99 days (2-3 days/location). Sampling time was carried out in the morning (07.30-10.30 WITA), afternoon (15.30-17.00 WITA), and evening (19.30-21.00) to ensure that nocturnal gastropods were sampled. However, during sampling activities, the gastropod community tended to be diurnal. In addition, a thorough sampling was also carried out on the areas of gastropods found (depth = 0-30 cm) (Purnama et al. 2019) using a swipe area technique and a 1 m^2 square plot with several repetitions adapted to research needs and of course the presence of gastropods at the specified location. Furthermore, a sampling of terrestrial gastropods was also carried out on river vegetation around the sampling point of aquatic snails, which are the habitat of the mainland snails. Terrestrial snails generally behave as climber snails around river vegetation, so the potential sampling area is close to the sampling location for aquatic snails. Then, the gastropod sample identification process (morphological based) is carried out in the Laboratory of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Universitas Halu Oleo, Kendari, Southeast Sulawesi, Indonesia. The sampling coordinates of the gastropod and their habitat types are presented in Table 1.

The collected gastropods were identified *"morphological based"* referring to specific *"identification keys"* for freshwater gastropods based on van Benthem (1946; 1959), Butot (1954), Edmondson (1966), Burch (1982), Dharma (1988), Haynes (1988; 1990; 2001; 2005), Tryon (1888); Rao (1989), Carpenter and Niem (1998), FAO (2005; 2011), Strong et al. (2008), Easton et al. (2012), and Eichhorst (2016a,b). Apart from textbooks, several *"reputable journals"* were also used to strengthen the identification results (*"double checklist"*), such as Liu et al. (1979), Brown (1983), Kristensen and Oggunnowo (1987), Pointier and Marquet (1990), Charoenchai et al. (1997), Köhler and Glaubrecht (2001), Zilch (2002), Appleton (2003), Facon et al. (2003), Bunje (2004); Glaubrecht and Köhler (2004), Global Invasive Species Database (2005), Strong et al. (2008), Tan and Clements (2008), Steinke et al. (2009), Marwoto and Isnaningsih (2011), Collins et al. (2012), Cowie and Hayes (2012), Tan et al. (2012), von Rintelen et al. (2014), Abdou et al. (2015), Appleton and Miranda (2015), Rosenberg (2015), Seddon and Rowson (2015), Chee and Siti-Azizah (2016), Ng et al. (2016), Abdou et al. (2017), Harding et al. (2019), Sutcharit et al. (2019), Krings et al. (2020), Bespalaya et al. (2021), Lopes-Lima et al. (2021), Pazilov and Umarov (2021), Neubauer et al. (2021; 2022a,b), Pranesh et al. (2021), Rangel et al. (2021), Sonowal et al. (2021), Vinarski et al. (2021), Yu et al. (2021), Bouly et al. (2022), Gladstone et al. (2022), Hah et al. (2022), Kirsch (2022) and Wiroonpan et al. (2022). The identification of gastropod communities was then tabulated based on their species with a detailed and systematic explanation of their respective habitats.

Table 1. Sampling coordinates of gastropods and their habitat types

Coordinate	Habitat type
-4,019, 122,655444	Sand/Gravel Substrate River
-4,12186, 122,614222	Mud-substrate river
-4,15094, 122,632139	Sand/Gravel Substrate River
-4,15178, 122,647278	Mud-substrate river
-4,15308, 122,646306	Sandy river
-4,22989, 122,716361	Sand/Gravel Substrate River
-4,23, 122,716472	Sand/Gravel Substrate River
-4,25817, 122,699556	Sand/Gravel Substrate River
-4,25822, 122,699472	Sand/Gravel Substrate River
-4,35372, 122,728861	Sand/Gravel Substrate River
-4,35378, 122,729361	Sand/Gravel Substrate River
-4,30925, 122,702444	Sand/Gravel Substrate River
-4,08811, 122,347639	Mud-substrate river
-4,08803, 122,303806	Sand/Gravel Substrate River
-4,10286, 122,261139	Sand/Gravel Substrate River
122,261, 122,259972	Sand/Gravel Substrate River
-4,11086, 122,248806	Embankment/Drainage
-4,11303, 122,179111	Embankment/Drainage
-4,13603, 122,150694	Mud-substrate river
-4,10939, 122,092389	Swamp (Aopa Swamp National Park)
-4,10942, 122,092306	Swamp (Aopa Swamp National Park)
-4,09158, 122,453694	Sand/Gravel Substrate River
-4,16028, 122,492667	Sand/Gravel Substrate River
-4,25081, 122,4835	Sand/Gravel Substrate River
-4,25067, 122,4835	Mud-substrate river
-4,30578, 122,486722	Sand/Gravel Substrate River
-4,30836, 122,491361	Mud-substrate river
-4,35608, 122,495417	Mud-substrate river
-4,37425, 122,482417	Ricefield/ricefield irrigation
-4,45214, 122,332222	Muddy sand substrate
-4,47286, 122,270861	Muddy sand substrate
-4,45989, 122,205639	Mud-substrate river
-4,44903, 122,149917	Mud-substrate river

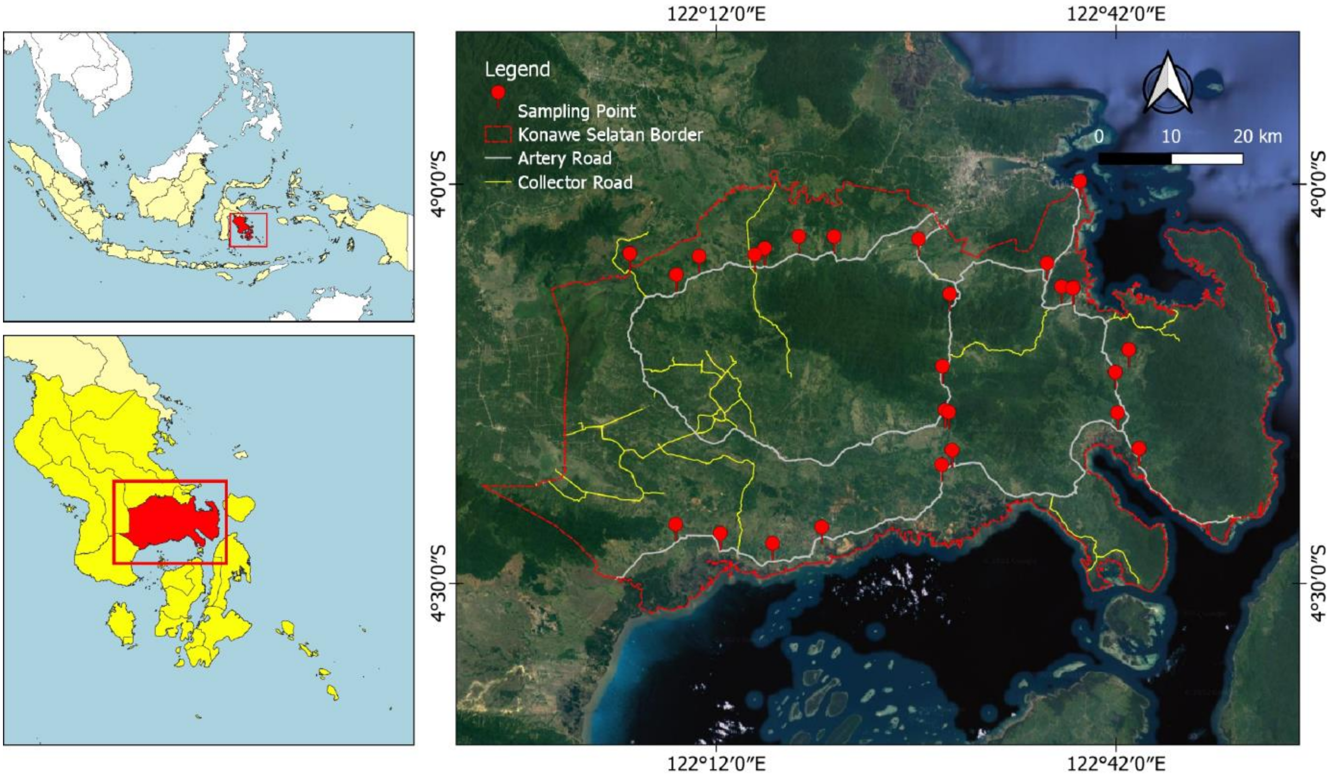

Figure 1. Map of research location in South Konawe District, Southeast Sulawesi, Indonesia

Data analysis

This study intends to analyze the potential of gastropods in a wider scope spatially to estimate with precision the description of freshwater gastropod resources in Southeast Sulawesi Province, especially in the South Konawe District, through research on the structure of the gastropod community. In addition, this research can indirectly justify the condition of inland waters at the research locus through the analysis of the gastropod ecology index. Therefore, the gastropod data was tabulated by type and analyzed using the following community structure formulation.

The gastropod abundance was analyzed based on Yasman (1998):

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

Where: A = abundance (Ind./m^2); xi = number of individuals (ind.); ni = sample plot (m^2).

The gastropod diversity was analyzed using the Shannon-Wiener diversity index based on Odum (1993):

$$H' = -\sum_{i=1}^{s}\left[\left(\frac{ni}{N}\right) x \text{ Ln}\left(\frac{ni}{N}\right)\right]$$

Where: H' = diversity index; Ni = the number of individuals of the i-th species; N = total number of individuals.

According to Wilhm (1975) the criteria for the Diversity Index are divided into 3 categories: H'<1.0 = low species diversity; 1.0<H'<3 = Medium species diversity; and H'>3 = high species diversity.

The Gastropod Evenness Index was analyzed according to Odum (1993):

$$E = \frac{H'}{\text{Ln S}}$$

Where: E = Evenness; H' = diversity index; S = number of types.

The criteria for the value of the Species Evenness Index are as follows: E<0.31 = low level of evenness; 0.31>E>1 = moderate level of evenness; and E>1 = high level of evenness.

The species richness index (Margalef index) was analyzed based on Ludwig and Reynolds (1988):

$$R = \frac{(S-1)}{\text{Ln N}}$$

Where: S = number of species; N = number of individuals

The criteria for the Margalef Species Richness Index are: D<2.5 = low level of species richness; 2.5> D > 4 = medium level of species richness; and D > 4 : high level of species richness.

The Dominance Index was calculated according to Odum (1993):

$$C = \Sigma\left(\frac{ni}{N}\right)^2$$

Where: ni = number of individuals to i and N = total number of individuals of all species.

The criteria for the dominance index are 0<C<0.5 = no dominant species and 0.5<C<1 = there is a dominant species.

The distribution pattern of gastropods was calculated using the Morisita Dispersion Index (Krebs, 1989):

$$ID = n\left\{\frac{\Sigma xi^2 - \Sigma xi}{(\Sigma xi)^2 - \Sigma xi}\right\}$$

Where: ID = Morisita Dispersion Index ID; n = Total number of sampling units; xi = Total number of species I; xi^2 = Number of i-th type.

The criteria for the type distribution pattern are:ID=0 = Random distribution pattern (R); ID>0 = clustered distribution pattern or Clummped (C); ID<0 = Regular or uniform distribution pattern (U).

RESULTS AND DISCUSSION

Result

There are 10 inland gastropod communities in the South Konawe District, consisting of 19 genera and 33 species. The types of gastropods found in inland waters of the South Konawe District are presented in Table 2.

The total number of samples obtained was 2635 individuals, dominated by snails of the type *M. tuberculata* (445 individuals) and *T. granifera* (437 individuals). Meanwhile, the snails with the lowest number were *Pila scutata* and *Faunus ater* (19 individuals, each of them). These snails were difficult to find in each sampling location because they have a unique habitat. Therefore, the individual numbers of each species are presented in Figure 2.

The abundance of gastropod populations in each sampling location showed a high range of 38-130 ind./m^2. In comparison, the species abundance tended to be dominated by snails from the Thiaridae family: *T. granifera*, *M. tuberculata*, *T. scabra*, and *T. winteri*, and the Neritidae family: *C. corona*. Species composition, species abundance, and gastropod abundance in each sampling location are shown in Figures 3 and 4.

The average abundance of gastropods was high, 79.85 ind./m^2 (Figure 3), with a species abundance of 0.58-13.48 ind./m^2 (Figure 4). The presence of invasive species *T. granifera* and *M. tuberculata* tended to affect the existence of other snails as they can eliminate the ecological role of other types of gastropods. Figure 3 showed variations in the abundance of different gastropods at each sampling location, but in general, the lowest abundance value obtained (38 ind./m^2) was still in the high category indicating a species richness of gastropods. The presence of certain species seemed to be limited due to the habitat characteristics. For example, *P. scutata*, *P. ampullacea*, and *P. polita* were found in the rice fields. The Neritidae snails were observed in the rocky rivers and estuaries with rocky substrates, while the Ariopanthidae family were generally found in the humid land areas with dense vegetation (canopy).

Gastropod ecological index

The gastropod ecological index was used to estimate the condition of inland water ecosystems on the ecological interaction system in their habitat space. The results of this analysis of the ecological index (diversity, uniformity, species richness, dominance, and distribution pattern) are presented in Table 3.

Table 2. Species of freshwater gastropods in South Konawe District, Southeast Sulawesi, Indonesia

Family	Genera	Species
Thiaridae	*Tarebia*	*Tarebia granifera*
Thiaridae	*Melanoides*	*Melanoides tuberculata*
Thiaridae	*Melanoides*	*Melanoides rustica*
Thiaridae	*Melanoides*	*Melanoides torulosa*
Thiaridae	*Melanoides*	*Melanoides plicaria*
Thiaridae	*Thiara*	*Thiara scabra*
Thiaridae	*Thiara*	*Thiara winteri*
Lymnaeidae	*Lymnae*	*Lymnae rubiginosa*
Planorbidae	*Amerianna*	*Amerianna carinata*
Planorbidae	*Indoplanorbis*	*Indoplanorbis exustus*
Ampullariidae	*Pila*	*Pila ampullacea*
Ampullariidae	*Pila*	*Pila polita*
Ampullariidae	*Pila*	*Pila scutata*
Ampullariidae	*Pomacea*	*Pomacea canaliculata*
Viviparidae	*Bellamya*	*Bellamya javanica*
Viviparidae	*Filopaludina*	*Filopaludina javanica*
Pachychilidae	*Faunus*	*Faunus ater*
Neritidae	*Clithon*	*Clithon corona*
Neritidae	*Clithon*	*Clithon squarrosus*
Neritidae	*Clithon*	*Clithon diadema*
Neritidae	*Clithon*	*Clithon oualaniense*
Neritidae	*Clithon*	*Clithon faba*
Neritidae	*Neritina*	*Neritina zigzag*
Neritidae	*Neritina*	*Neritina pulligera*
Neritidae	*Neritina*	*Neritina labiosa*
Neritidae	*Neritina*	*Neritina squamaepicta*
Neritidae	*Neritina*	*Neritina turrita*
Neritidae	*Septaria*	*Septaria porcellana*
Neritidae	*Vittina*	*Vittina coromandeliana*
Achatinidae	*Achantina*	*Achantina fulica*
Ariophantidae	*Naninia*	*Naninia citrina*
Ariophantidae	*Hemiplecta*	*Hemiplecta abbasi*
Ariophantidae	*Microparmarion*	*Microparmarion exquadratus*

Table 3. Gastropod ecological index value in South Konawe District, Southeast Sulawesi, Indonesia

Index	Value	Category
Diversity (H')	3.03	High
Evenness (E)	0.87	Moderate
Species Richness (R)	4.06	High
Dominance (C)	0.08	No one dominates
Distribution Pattern (Ip)	0.02	*Clummped*

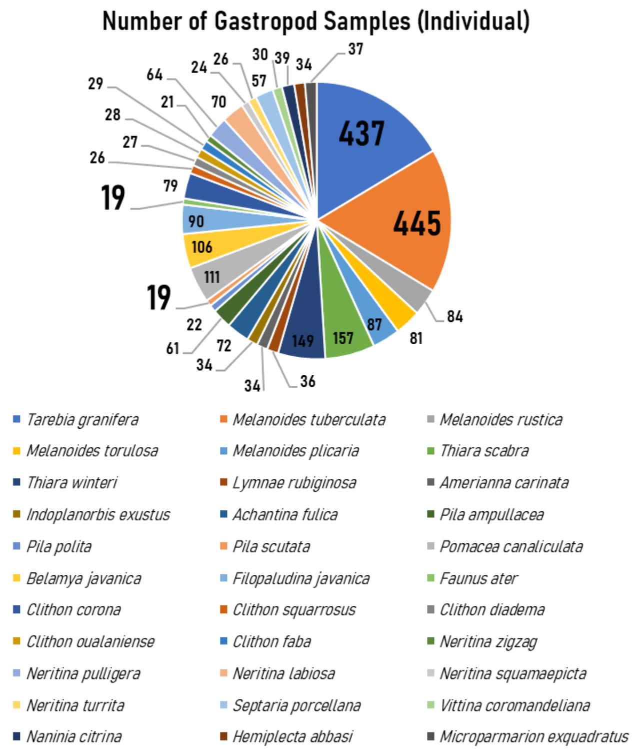

Figure 2. Number of individuals for each type of gastropod at 33 sampling locations in South Konawe District, Southeast Sulawesi, Indonesia

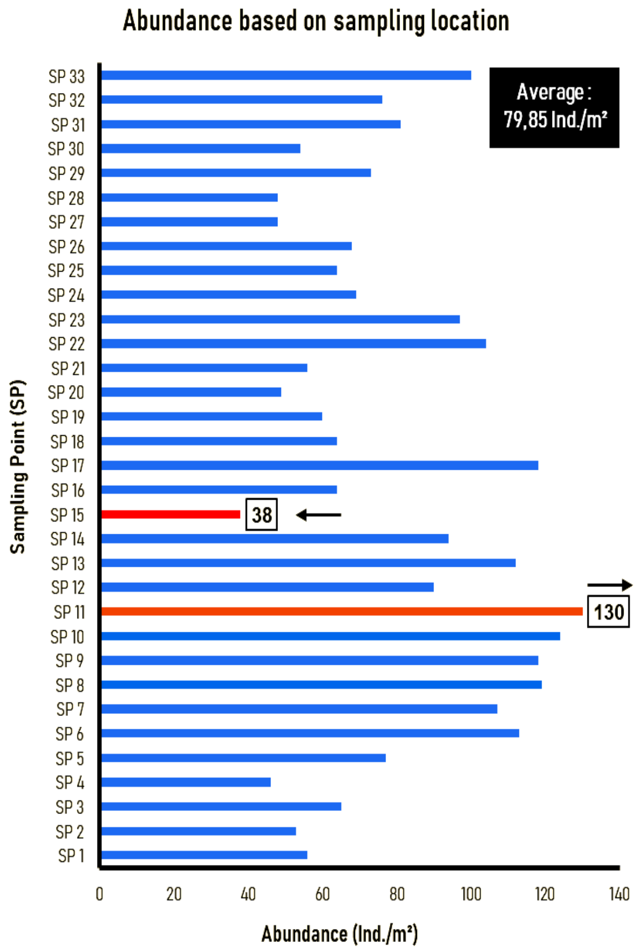

Figure 3. Gastropod community abundance based on sampling location (spatial) in South Konawe District, Southeast Sulawesi, Indonesia

Discussion

The high diversity of gastropod communities in the South Konawe District is closely related to the species composition, both in number and individual representation of each species. The analysis showed a high tendency of the spetial abundance of gastropods (38-130 ind./m^2) and there was an individual representation of each species in the ecosystem (0.58-13.48 ind./m^2). This implied that there was no dominance of snails because the distribution of each species is generally clustered. This study found that two types of snails from the Thiaridae family had the highest species abundance compared to other species: *M. tuberculata* (13.48 ind./m^2) and *T. granifera* (13.24 ind./m^2). These two species were confirmed as invasive freshwater snails (Charles H and Dukes JS 2007; Didham et al. 2007; Ruiz et al. 2011; Moslemi et al. 2012; Miranda and Perissinotto 2014; Rustiasih et al. 2018) and they have invaded the mainland waters of the Southeast Sulawesi region, both “land clusters” (North Kolaka District, Kolaka District, East Kolaka District, Bombana District, Konawe District, North Konawe District, South Konawe District, and Kendari City) and “archipelagic cluster” (Buton District, South Buton District, North Buton District, Muna District, and Baubau City) (Sirza et al. 2020; Purnama et al. 2020; 2021; 2022a).

These two invasive snails might affect the survival of indigenous species even though, in the current study, they did not have a detrimental ecological effect. The presence of these invasive species in our sampling areas was still in balance with other types of gastropods, as indicated in the proportion of individual representatives of each species in the population and the number of species found in the high category. This implies that the current influence of certain species in the ecological space is still very small (Purnama et al. 2022b). Arbi (2012) and Tarida et al. (2018) mentioned that the high diversity of gastropod species is generally caused by several factors, such as a large number of species and the individual representation of each species that has the same or even tendency. This study’s gastropod uniformity index category was moderate (E= 0.87). This is due to invasive gastropods that were abundant at each sampling location, together with other types of snails. Odum (1993) mentioned that the moderate uniformity value indicates the dominance of certain species, but their effect is still very small because the representation of other species is also quite large. In this case, the condition of organisms is still stable.

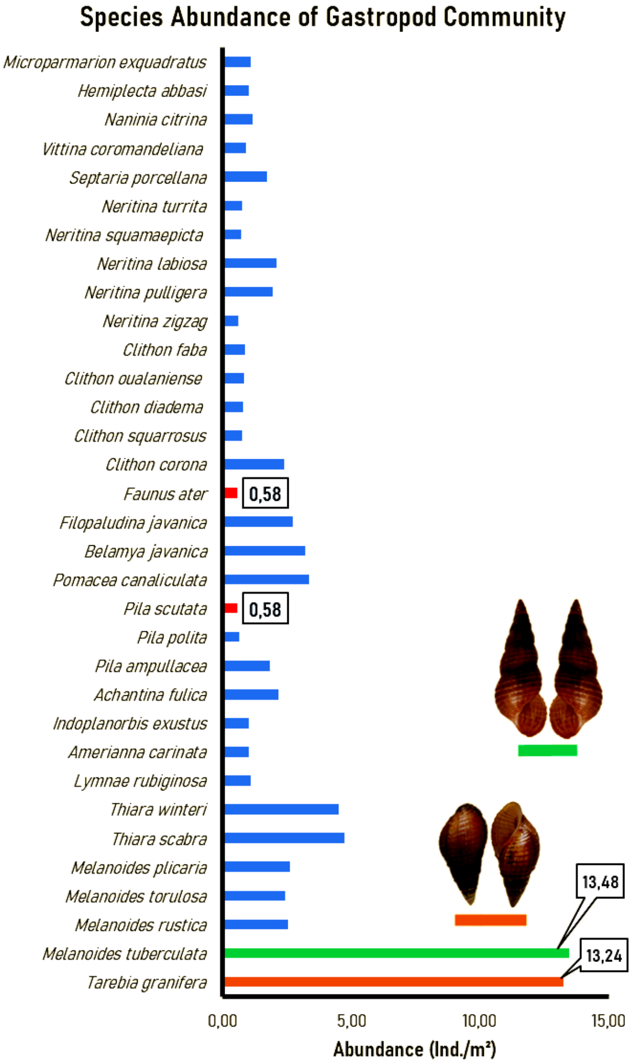

Figure 4. The composition and abundance of gastropod species in South Konawe District, Southeast Sulawesi, Indonesia

The gastropod community of the South Konawe District occupied a habitat where the invasive alien species present, such as *T. granifera* and *M. tuberculata* (Murray 1964; Livshits and Fishelson 1983; Livshits et al. 1984; Heller and Farstey 1990; Rader et al. 2003; Facon et al. 2005; Daniel et al. 2019; Purnama et al. 2020; 2021). Most of the natural and artificial inland waters in the South Konawe District were occupied by these two alien species. Similarly, it has been indicated that *T. granifera* and *M. tuberculata* were found in all typical freshwater habitats in Southeast Sulawesi Province and always dominated the niches they inhabited (Purnama et al. 2019) and Purnama et al. (2020). Furthermore, Sirza et al. (2020) and Purnama et al. (2021) stated that *T. granifera* can eliminate the native species in the ecosystem due to their adaptive behavior to environmental changes and the ability to reproduce by parthenogenesis. These two things have made the population of *T. granifera* uncontrollable, especially in Southeast Sulawesi (Chuboon et al. 2013; Veeravechsukij et al. 2018; Oliveira et al. 2020; Purnama et al. 2020; 2021; Sirza et al. 2020; Malatji et al. 2021; Nguyen et al. 2021; Makherana et al. 2022; Yin et al. 2022). A potential threat might also come from *M. tuberculata* (Facon et al. 2005; Daniel et al. 2019; Barros et al. 2020; Khanam et al. 2020; Lopes et al. 2020; Okumura and Rocha 2020; Oliveira et al. 2020; Alfaro et al. 2021; Lopes et al. 2021; McClure 2021; Bose et al. 2022; Tolley-Jordan et al. 2022), although its invasion rate was not as high as *T. granifera*. These two invasive snails are always found in all types of freshwater habitats (rivers, lakes, swamps, embankments, dams, rice fields, and drainage), and the range of population density is quite high when they are found in water (25-67 ind./m^2) (Purnama et al. 2019; 2021; 2022a,b). Although the influence of invasive snails is relatively small, it does not mean that a potential invasion is also small and narrow. Therefore, this study can become a preventive step to protect the indigenous gastropod resources in South Konawe District. In the end, the results of the analysis of the ecological index of gastropods in the South Konawe District showed an ecological equilibrium condition, in other words, the gastropod community was in a stable condition base on the community structure.

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