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Ecological index of freshwater gastropods in Kolaka District, Southeast Sulawesi, Indonesia

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Abstract. *Salwiyah, Purnama MF, Syukur. 2022. Ecological index of freshwater gastropods in Kolaka District, Southeast Sulawesi, Indonesia. Biodiversitas 23: 3031-3041.* Kolaka District is one of the existing centers of high freshwater gastropod diversity in Southeast Sulawesi Province, Indonesia. more than 30 species of inland gastropods occupy this area and some of them (species) are used by local communities as food (daily consumption). This research was conducted for 4 months, namely January-April 2021 in Kolaka District, Southeast Sulawesi, Indonesia. The purpose of this study was to determine the ecological index (abundance, diversity, evenness, species richness, dominance, and distribution pattern) of the inland gastropod community in Kolaka. The sampling location of gastropods was determined qualitatively using the purposive sampling method and sampling using a simple random sampling technique (Quantitative based). Gastropod samples were collected manually (hand picking) using a paralone pipe (3.5 inches), Sieve (1 mm), and Gloves. The total gastropod sample obtained during the study was 1929 individuals consisting of 9 families, 19 genera, and 33 species. The average abundance of the gastropod population reached 96.45 ind./m^2 and the abundance of gastropod species ranged from 0.75-15.05 ind./m^2. Overall, the results of the gastropod ecological index analysis showed a stable condition, where the diversity of gastropod species was categorized as high (H': 3.20), moderate evenness (E: 0.90), and high species richness (R: 4.23), dominant dominance. showed that there were no dominant species (C: 0.1) and the distribution of gastropods showed a clumped pattern (Ip: 0.01). Empirically the ecological index data is a scientific justification related to the sustainability of inland water ecosystems or a description of the current freshwater homeostasis system in Kolaka.

Keywords: Aquatic snail, high diversity, inland waters, Kolaka District, polymorfism, terrestrial snail

INTRODUCTION

Inland fisheries are one of the leading sectors of Southeast Sulawesi Province, especially in Kolaka District, Southeast Sulawesi Province, Indonesia (BPS Kolaka District 2021). Communities in this area utilize freshwater resources (fish and non-fish) as a source of food for daily consumption. Some of these commodities include fish groups such as tilapia (*Oreochromis niloticus*), goldfish (*Cyprinus carpio*), catfish (*Clarias batrachus*), snakehead (*Channa striata*), tilapia (*Oreochromis mossambicus*), gourami (*Osphronemus goramy*), and pomfret (*Colossoma macropomum*) and communities of shellfish (bivalves) and snails (gastropods) such as kijing (*Anodonta woodiana*), remis (*Corbicula javanica*), pokea (*Batissa violacea*), kowoe (*Pila ampullacea*), and tutut (*Filopaludina javanica*, *Bellamya javanica*) (Jukri et al. 2013; Purnama et al. 2019a, 2019b, 2019c). One of the largest groups of aquatic resources that make up the freshwater ecosystem of Kolaka is the gastropod community or a group of organisms from the phylum mollusks (soft-bodied invertebrates), which are generally known as single-dwelling animals (shells), like snails (Purnama et al. 2019a; Purnama 2022).

Generally, the adaptation behavior of gastropods to the aquatic environment is by sticking and having sessile properties (Yolanda 2014). The existence of gastropods can be found easily in the world because these animals have cosmopolitan nature or are able to live from the top of high mountains to the bottom of the sea though. Terrestrial gastropods can be found at the top of the mountain to the back of the mangrove forest. Generally, they live attached to trees, shrubs, rocks, fallen tree trunks, and litter. Most terrestrial gastropods live in litter, especially thick litter (Heryanto 2013). Among the typical freshwater biota above, the gastropod community is one of the aquatic biotas that has not been widely utilized by the local community in Southeast Sulawesi.

Meanwhile, the gastropod population in inland waters of Kolaka is classified as abundant because it consists of ±30 species (Purnama et al. 2019). In addition, gastropods not only provide economic benefits but also ecologically have a very important role as part of the food chain and food web (Andriati et al. 2020; Purnama et al. 2022a, 2022b). Moreover, the relatively sessile nature of gastropods or low ability to move places makes it an important bioindicator or index to analyze the negative impact of human activities on the aquatic environment (Kohan et al. 2012; Petracco et al. 2014; Febiansi et al. 2018 Esposito et al. 2022; Khasanah et al. 2022; Liu et al. 2022; Pergiwa et al. 2022; Ryabushko et al. 2022; Sriwahjuningsih and Fitri 2022; Wahyuningsih and Umam 2022; Zaidi et al. 2022).

The importance of the role of the gastropod community from an economic and ecological perspective needs to be followed by management efforts so that the population in the waters remains sustainable. Therefore, research on the ecological index of gastropods is very important to do, as a first step in revealing the potential of the gastropod population in Kolaka, considering that research on the gastropod ecological index (district-scale) has never been carried out in Southeast Sulawesi, so the overall potential of inland water gastropod resources can not be estimated with certainty. On the other hand, this research is also important because it contains significant benefits in terms of the sustainability of the aquatic environment, namely empirically being able to estimate the balance of the ecosystem or freshwater homeostasis system in Kolaka through the results of the analysis of the ecological index parameters of the gastropod community measured. The purpose of this study was to determine the structure of the gastropod community in "natural" (rivers, swamps, and lakes) and "artificial" inland waters (dams, drainage, rice fields, irrigation canals, and reservoirs) in Kolaka District, Southeast Sulawesi, Indonesia.

MATERIALS AND METHODS

This research was divided into two stages, namely (i) sampling or sample collection and (ii) observation/ sampling identification. The gastropod sampling activity was carried out for 4 months (January-April 2021) in Kolaka District, Southeast Sulawesi Province, Indonesia (Figure 1) and sample observations or the process of identifying gastropod species were carried out at the Aquatic Resources Management Laboratory, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kendari, Indonesia.

The location of the sampling of gastropods was determined qualitatively using the purposive sampling method or the research station was placed in inland waters, which is an existing area of the gastropod community, while the sampling of gastropods used quantitative methods with a simple random sampling technique. Gastropod samples found at the study site were collected manually (hand picking) without special fishing gear using hand scoops, gloves, and a square transect measuring 1 m^2. Sampling activities or collection of gastropod community samples at each location (Table 1) took 3-4 days, so the total time required for the sampling process was ±80 days. Sampling time was carried out in the morning (07.30-10.30 WITA), afternoon (15.30-17.00 WITA), until evening (19.30-21.00) to ensure that nocturnal gastropods were sampled, although during sampling, the trend of the gastropod community was relatively diurnal.

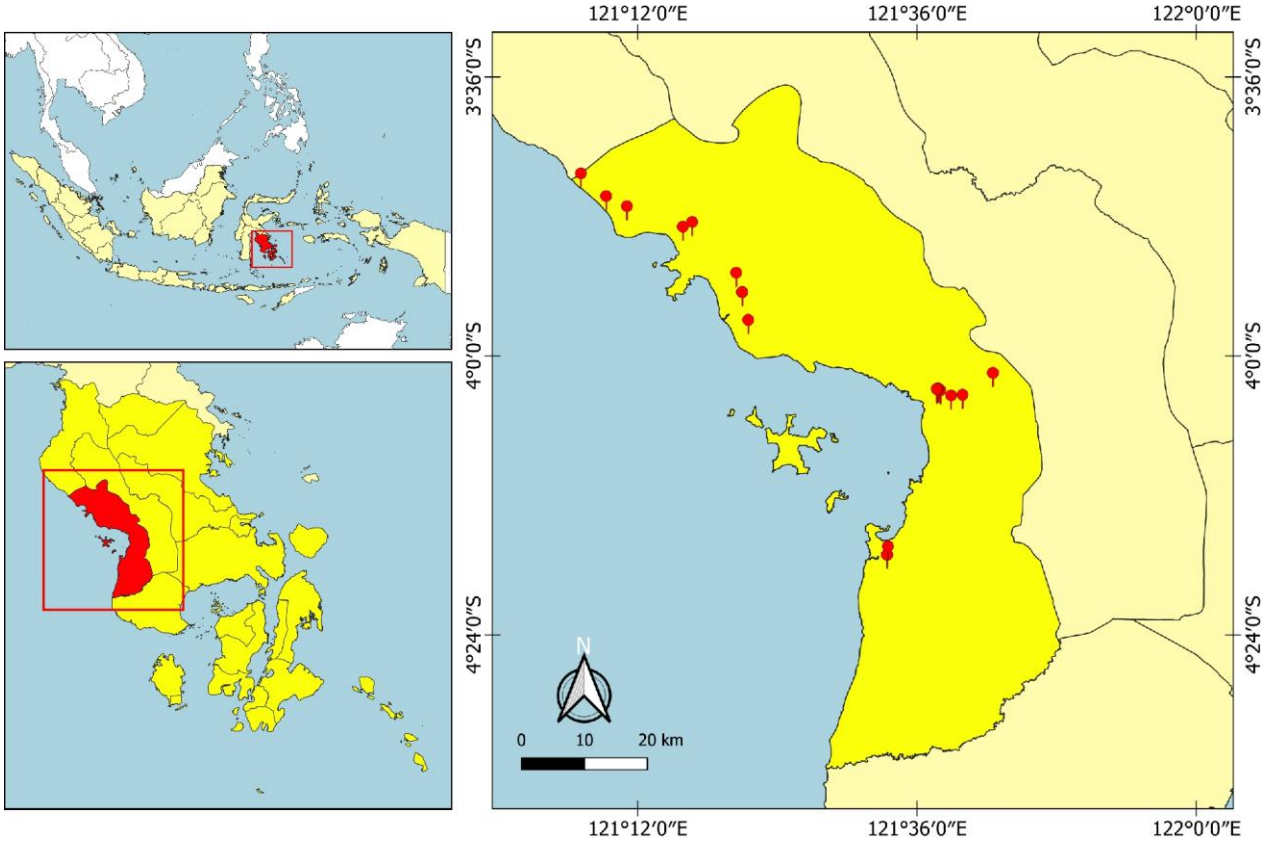

Figure 1. Map of research location in Kolaka District, Southeast Sulawesi Province, Indonesia

Table 1. Coordinates of sampling location and gastropod habitat type

Coordinate	Habitat type
-3,75931, 121,119556	Shortest River/Spring/Tamborasi River
-3,79183, 121,155722	Sand/Gravel Substrate River
-3,80633, 121,185556	Rocky River
-3,83581, 121,265611	Sand/Gravel Substrate River
-3,82892, 121,279083	Sand/Gravel Substrate River
-3,90175, 121,341972	Embankment/Drainage
-3,92972, 121,350444	Rocky River
-3,92944, 121,350528	Sand/Gravel Substrate River
-3,96947, 121,359083	Sand/Gravel Substrate River
-4,07042, 121,634556	Rocky River/Dam
-4,0695, 121,630139	Rice Fields
-4,068, 121,631667	Embankment/Drainage
-4,06803, 121,630361	Embankment/Drainage
-4,06856, 121,629389	Embankment/Drainage
-4,07781, 121,649944	Rice Field Irrigation Channel
-4,07686, 121,666333	Rocky River
-4,0455, 121,70975	Sand/Gravel Substrate River
-4,30636, 121,558139	Embankment/Rice Drainage
-4,13211, 121,558833	Rice Field Irrigation Channel
-4,29419, 121,559528	Sand/Gravel Substrate River

In addition, sampling activities were also carried out thoroughly in areas where gastropod communities were found (depth: 0-30 cm) (Purnama et al. 2019a) using a swipe area technique and a square plot (1 m^2) with several repetitions according to research needs and of course the presence of gastropods at a predetermined location. Then, the sampling of terrestrial gastropods was also carried out in the river vegetation community around the sampling point, which became the habitat of the mainland snail. Terrestrial snails generally have the behavior of living as climber snails around river vegetation so that the potential sampling area is close to the sampling location of aquatic snails. The following are the coordinates of the gastropod sampling locations and their habitat types throughout Kolaka (Table 1).

Furthermore, the types of gastropods found in the inland waters of Kolaka were identified using several search keys, including Tryon (1888); van Benthem (1946, 1959); Butot (1954); Edmondson (1966); Burch (1982); Carpenter and Niem (1988); Dharma (1988); Haynes (1988, 1990, 2001, 2005); Subban (1989); FAO (2005, 2009); Strong et al. (2008); Easton et al. (2012); and Eichhorst (2016). In addition to reliable text books, several reputable journals were also used to find out the results (double checklist), such as Liu et al. (1979); Brown (1983); Kristensen and Oggunnowo (1987); Haynes (1988, 1990, 2005); 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 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); Neubauer et al. (2021); Pazilov and Umarov (2021); 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); Neubauer et al. (2022a, 2022b); Wiroonpan et al. (2022).

Data analysis

The following are the parameters of the ecological index and the formulation of the formula used in analyzing the community structure of inland gastropods in Kolaka.

Abundance

Gastropod abundance was analyzed using Yasman's (1998) formulation:

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

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

Diversity

Gastropod diversity analysis used the Shannon-Wiener diversity index (Odum 1993), with the formula:

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

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, namely: H'<1.0: low species diversity; 1.0<H'<3: Medium species diversity; and H'>3: high species diversity.

Evenness

The Gastropod Uniformity Index was analyzed using the formula according to Odum (1993), namely:

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

Where, E: evenness index; H': diversity index; S: number of species.

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.

Species richness index

The species richness index (margalef index) was analyzed based on the formula formulation according to Ludwig and Reynolds (1988), namely:

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

Where, S: number of species; N: number of individuals.

The criteria for the value of the Margalef Specific Wealth Index are as follows: 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.

Dominance index

The Dominance Index is calculated using the formulation according to Odum (1993), namely:

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

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

The criteria for the dominance index consist of 0<C<0.5: no dominant species and 0.5<C<1: there is a dominant species.

Distribution pattern

The distribution pattern of gastropods was calculated using the Morisita Dispersion Index (Krebs 1989). The formulation of the Morisita dispersion index is:

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

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 as follows, ID=0: Random distribution pattern (R); ID>0: clustered distribution pattern or Cl ummped (C); ID<0: Regular or uniform distribution pattern (U).

RESULTS AND DISCUSSION

Diversity

The total gastropod samples collected during the study were 2635 individuals. The species composition found at the sampling location tends to be dominated by certain types. The dominant species that exist are classified as invasive or invasive alien species (IAS). Similar to other regencies/cities in Southeast Sulawesi (Purnama et al. 2020; Sirza et al. 2020; Purnama et al. 2021), in the inland waters of Kolaka, there are also alien species invasions such as *Tarebia granifera* (Chuboon et al. 2013; Veeravechsukij et al. 2018; Oliveira et al. 2020; Purnama et al. 2020; Sirza et al. 2020; Malatji et al. 2021; Nguyen et al. 2021; Purnama et al. 2021; Makherana et al. 2022; Yin et al. 2022) and *Melanoides 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).

This invasive species was recorded to have a much larger number of individuals than the others, where *T. granifera* reached 301 individuals and *M. tuberculata* reached 212 individuals. The results of the identification of inland gastropod communities in Kolaka obtained 33 species consisting of 9 families (Achantinidae, Ampullariidae, Ariophantidae, Lymnaeidae, Neritidae, Pachychilidae, Planorbidae, Thiaridae and Viviparidae) 19 Genus (*Achatina, Amerianna, Bellamya, Clithon, Filopaludina, Hemiplecta, Indoplanorbis, Lymnaea, Microparmarion, Melanoides, Naninia, Neritina, Pila, Pomacea, Septaria, Tarebia, Thiara* and *Vittina*). After being classified according to family to type, it was reported that this study identified 2 groups of gastropods based on their existing habitat areas, namely "aquatic snails" and "terrestrial snails".

There are 4 species of land snails, each of which comes from the families Achantinidae and Ariophanthidae, namely *Achatina fulica, Naninia citrina, Hemiplecta abbasi* and *Microparmarion exquadratus* and 29 species of aquatic snails (*Amerianna carinata, Bellamya javanica, Clithon corona, Clithon diadema, Clithon faba, Clithon faba, Clithon oualaniense, Clithon squarrosus, Filopaludina javanica, Faunus ater, Indoplanorbis exustus, Lymnae rubiginosa, Melanoides plicaria, Melanoides rustica, Melanoides torulosa, Melanoides tuberculata, Neritina labiosa, Neritina pulligera, Neritina turrita, Neritina squamaepicta, Neritina zigzag, Pila ampullacea, Pomacea canaliculata, Pila polita, Pila scutata, Septaria porcellana, Tarebia granifera, Thiara scabra, Thiara winteri,* and *Vittina coromandeliana*). The total number of individuals of each species is presented in Figure 2.

Figure 2 above shows the representation of each species in the community. The average number of individuals shows a relatively equal distribution across species and there are only two species that tend to dominate, but their influence on the ecosystem is very small. The average proportion of individual gastropod communities in Kolaka is fairly balanced with the types of snails typical of mainland waters which vary in form (polymorphic) and ecological systems. Some of the most common gastropod families found in each research location were the trumpet snail or Thiaridae and the Neritidae family or snails that inhabit rocky river areas and have a swift current (lotic). The two groups of snails were always found at every sampling location and were able to occupy all types of inland waters (natural and artificial). The results of the analysis of the mean population abundance of inland water gastropods in Kolaka spatially (sampling points) show a fairly different range of values, namely 54-139 ind./m^2 (Figure 3) and species abundance ranging from 0.75-15.05 ind./m^2 (Figure 4).

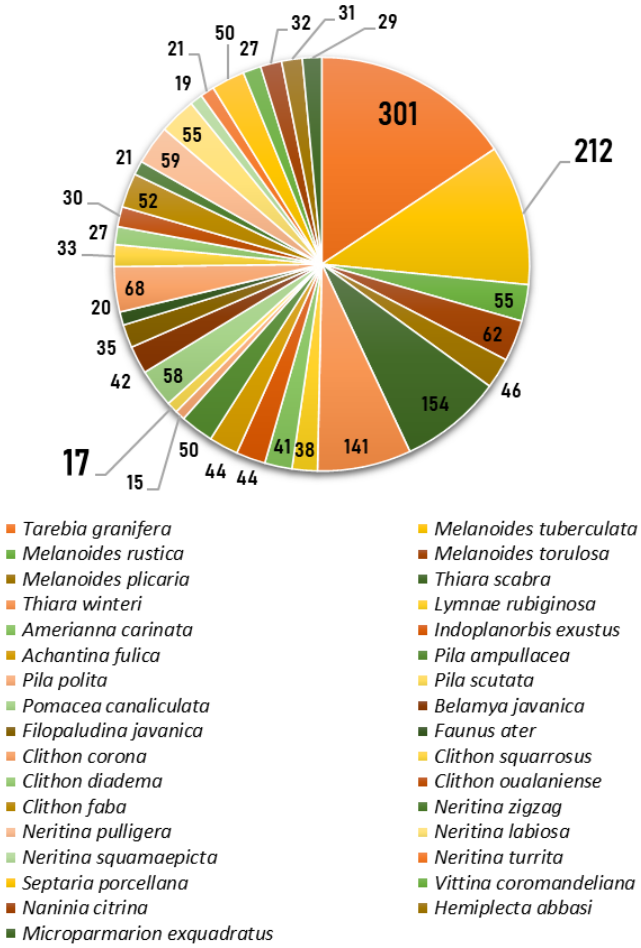

Figure 2. Number of individuals for each type of gastropod at 20 sampling locations in Kolaka District, Southeast Sulawesi Province, Indonesia

In general, the average abundance of gastropods at each study site is in the high category, and the distribution of individual representatives of each species is evenly distributed even though there are two relatively dominant species. Several species were also recorded to have low species abundance, this is closely related to the specific habitat types of these snail species, such as *P. polita* and *P. sculata*, which are scattered in rice fields/rice field irrigation canals and are currently also difficult to find or their populations are difficult to find. Tend to be dominated by gold snails (*P. canaliculata*) and *F. ater* or snails that specifically inhabit brackish waters with the rocky sand substrate (solid). This type of snail family Pachychilidae is mostly found in brackish water lakes that are directly connected to the surrounding sea waters. In addition, this study also found several species of terrestrial snails that have habitats on land and inhabit distinctive niches, such as the surface of leaves, stems, and twigs of trees. These climbing snails are divided into 2 groups based on their morphological conditions, namely (1) having a shell and (2) without a shell (slug) or resrespo (in the local Javanese language).

In several places in Kolaka, this terrestrial snail is known as a plant/vegetable pest and not infrequently used as aquaculture biota for the needs of live fish feed, such as *A. fulica*. It is known that land snails have a high protein content (Jibril 2021) and are economical in development, and can reduce operational costs. The number of individuals spread evenly at each station and the presence of various gastropod species indicates environmental stability in the inland aquatic ecosystem of Kolaka. In other words, the gastropod community is still in the range of equilibrium or homeostasis. Overall, the abundance of gastropod species and abundance at each sampling location in Kolaka is presented in detail and systematically in Figures 3 and 4.

Ecological index of gastropod in Kolaka

The results of the analysis of all gastropod ecological index parameters in inland waters of Kolaka, Southeast Sulawesi are presented in Table 2.

The gastropod diversity index (H') in Kolaka as a whole shows a high category (H': 3.20). Average index value (E: 0.90). The high species richness index (R: 4.23) and the dominance index indicated that there were no dominant species (C: 0.10). Meanwhile, the distribution of gastropods in Kolaka showed a clustered pattern (Clumped) or Ip: 0.01. The ecological index value above shows the gastropod community in the inland waters of Kolaka in a stable condition.

Discussion

The ecological index of inland gastropod communities is an indicator of ecosystem stability as indicated by the variability of species diversity, species evenness, and species dominance of a group of sessile organisms capable of recording inputs of organic and inorganic materials that enter their habitat (Octavina et al. 2019; Dewiyanti et al. 2021; Melati et al. 2021; Stanković et al. 2021; Purnama et al. 2022b; Valentino et al. 2022). Kolaka is one of the regions in Southeast Sulawesi Province with a high diversity of inland gastropod resources (Purnama et al. 2019a). This is a potential area that requires optimal and sustainable utilization and management efforts. This study noted that the gastropod diversity index (H') showed a high category (3.20) (Wilhm 1975). The uniformity index is moderate (E: 0.90) or meets the e category >0.6 (Krebs 1985). Species richness is directly proportional to the diversity index, which is in the high category (R: 4.23) (Ludwig and Reynolds 1988) and the dominance index value is very low or indicates the absence of a dominating species (C: 0.1), where the value of C meets the criteria of $0<C<0.5$ (Simpson 1949; Odum 1993).

The composition of the ecological index values above (Table 2) shows the balance of the gastropod community in their habitat in the inland waters of Kolaka. The high category in the aspect of species diversity is basically closely related to the number of gastropod species or there is an individual representation that tends to be the same between species in the community. This condition can be seen from the results of the analysis of the abundance of gastropods based on the type and sampling location, where

the distribution of values has the same tendency. This is in line with Latuconsina's (2019) statement that the diversity index value can indicate the balance or at least the diversity of species of an organism. If all the individuals of a community come from different species, the highest diversity index value will be obtained, whereas if it comes from only one species, the lowest value will be obtained. If the proportion between species is the same in a community, it can be said to have high species diversity.

However, if there are several species that have a large dominance, then the diversity is low. The species diversity of a high community will lead to species interactions involving energy transfer, competition, predation, and the division of niches that are more complex, causing ecological stability. Furthermore, Wahyuni et al. (2017) stated that a community has high diversity if all species have relatively the same or almost the same abundance and no major dominance is found. Then, Arbi (2012); Nurfitriani (2017); Tarida et al. (2018); Laraswati et al. (2020) and Stanković et al. (2021) state that the high and low diversity index values are caused by several factors, including the number of individuals (the same or evenly) and the species obtained. If a community has a moderate value of diversity, it is assumed that there will be an interaction between species that will lead to competition, sufficient productivity, fairly balanced ecosystem conditions, and moderate ecological pressure. The species richness variable basically has a direct relationship with species diversity, so the value of gastropod species richness in this study is also in the high category. This phenomenon generally occurs in ecosystems with a large number of species and individuals representing their species in the habitat space. In other words, this condition occurs in stable habitats or lacks ecological pressure due to anthropogenic activities (Purnama et al. 2022b).

Macintosh et al. (2002) and Rau et al. (2013) revealed that the value of the wealth index tends to be high if a community has a large number of species and each species is represented by one individual. The value of the species uniformity index in this study is close to 1 (moderate), and the dominance index is close to 0, meaning that the individual representation of each species is towards an even (stable) or uniform (intraspecific) trend because there are no certain species that dominate, although there are 1-2 types of snails that have a higher number of individuals, the effect is still very small because it can be balanced by other types of gastropods. As illustrated by the index values for species diversity and species richness (stable conditions), each parameter of the ecological index has its own relationship so that when one aspect is known, the other aspects also tend to be predictable. Latuconsina (2019) states that the uniformity index is used to see uniformity, where the greater the uniformity index indicates an almost even and uniform abundance of individuals between species. High species uniformity indicates ecological stability. Vijapure and Sukumaran (2019) stated that the greater the evenness index value, the greater the uniform type of taxa.

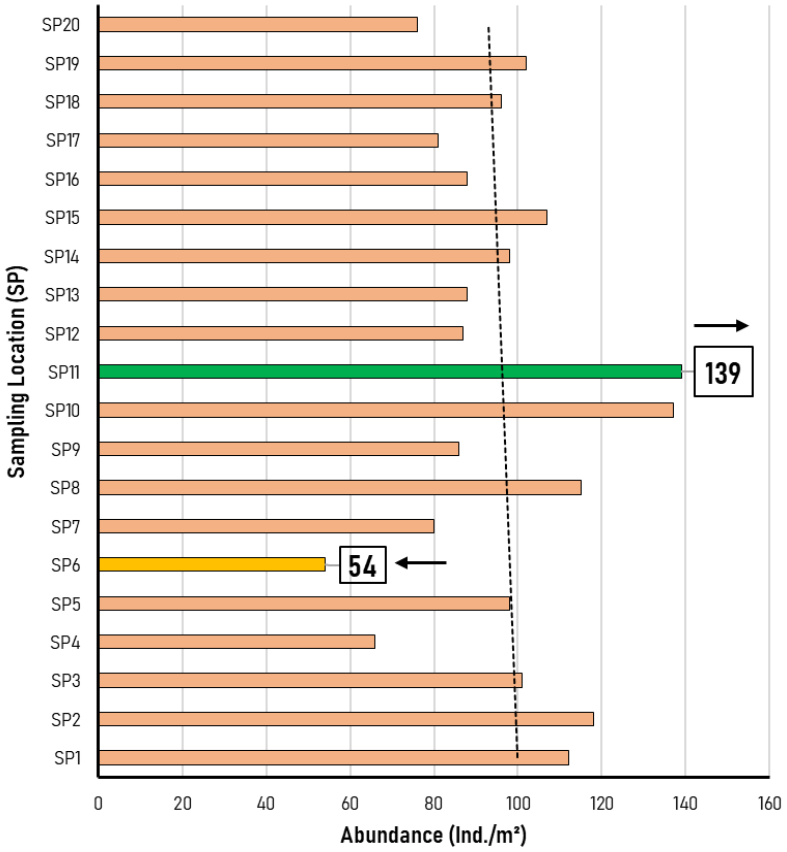

Figure 3. Gastropod community abundance based on sampling location (spatial) in Kolaka District, Southeast Sulawesi, Indonesia

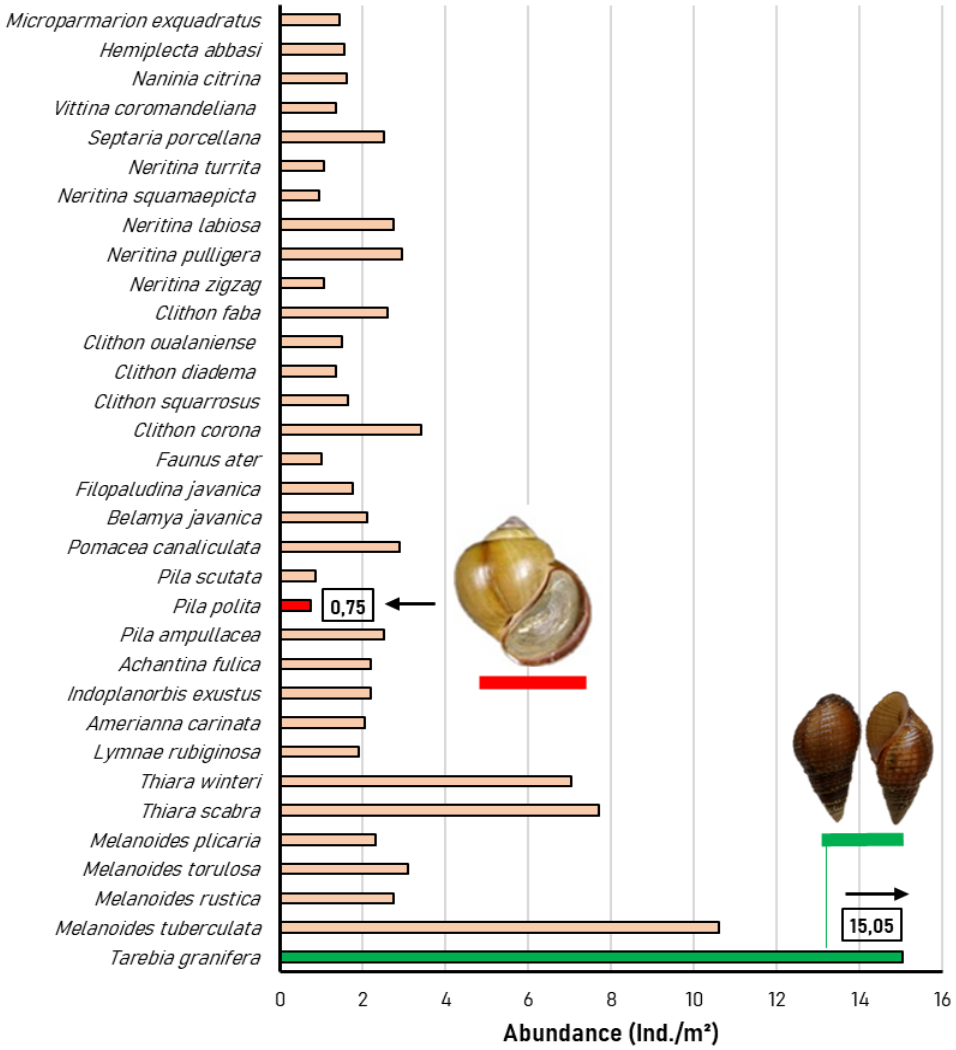

Figure 4. The composition and abundance of gastropod species in Kolaka District, Southeast Sulawesi, Indonesia

Furthermore, Yusuf and Kadim (2019); Pritchard and Martel (2020) state that a low dominance index is related to the evenness index. The low dominance index in this study indicates that the gastropod community in Kolaka is in good habitat condition, although it is also an existing area of invasive alien gastropods (IAS) such as *Tarebia granifera* and *Melanoides tuberculata* and several other invasive species, its influence on the waters is relatively small. This phenomenon is closely related to the distribution of invasive species, which tend to clump together so that interspecific competition is much more likely than intraspecific. However, serious attention needs to be given to controlling as early as possible before causing ecological and economic losses in the future. These invasive alien species (IAS) have been spread evenly throughout the sampling locations in Kolaka. Purnama et al. (2019a) and Purnama et al. (2020) stated that Kolaka is one of the distribution areas for the alien species *T. granifera* and *M. tuberculata* in Southeast Sulawesi. Oktavianti et al. (2014) asserted that if the dominance index in a community is close to 0 then no species dominate other species, this indicates that the condition of the community structure is in a stable condition. The dominance index provides an overview of the biotic organisms that dominate an ecological community. The dominance index value can describe if at the time of data collection, there is a species of organism that is more abundant than other species. High dominance indicates that there is energy transfer through food webs that are more dominated by certain species, causing ecological instability (Latuconsina 2019).

The distribution of gastropods in Kolaka shows a clumped pattern. Naturally, this type of gastropod distribution has consequences for each species in its ecological niche, where this condition triggers interspecific competition between gastropod communities for living space and food. This is similar to Odum's (1993) statement that the distribution of clustered species is a common dispersion pattern in nature. This condition occurs due to the collection of individuals in the face of dynamic changes in weather and seasons, and changes in habitat and reproductive processes, thereby increasing competition between individuals for food and space. "In the end, based on the results of the analysis of all gastropod ecological

index parameters, it can be concluded that the condition of the inland water ecosystem of Kolaka is still in a stable condition or the aquatic environment is in equilibrium (Homeostasis).

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