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Research

Freshwater Gastropod Diversity in The Selected Lotic Environment, Betong, Sarawak, Borneo

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ABSTRACT

Freshwater Gastropoda can be considered as the biological indicator in ecosystems such as rivers, streams, lakes, and ponds. The objectives of this study are to identify freshwater gastropod species, diversity, and distribution along Sungai Penebak, Sungai Nanga Tiga, and Sungai Kabo in the Betong division. The study was conducted on 10 November 2020. A 50 m transect was laid on the riverbank of all three stations. The existing specimens were counted and collected from each sampling point and stored were taken to the laboratory for species identification. The diversity index and morphological study of freshwater gastropods were performed. Five species of freshwater gastropods belonging to four families were discovered. The five species of freshwater gastropods consisted of *Sulcospira pageli*, which shows great abundance, followed by *Clea nigricans*, *Brotia costula*, *Pila ampullacea*, and *Vittina pennata*. The diversity indices of collected Gastropoda species from the different stations, for instance, Shannon-Weiner diversity index (H'), Pielou's evenness index (J'), and Margalef's richness index were assessed; where station 3 showed higher diversity of Gastropoda compared to other two stations. The information presented in this paper might be helpful for ecological wealth studies and considered as the baseline data for the stream ecosystem in Sarawak, Malaysia.

Key words: Betong, diversity indices, freshwater Gastropoda, Malaysian Borneo, Pachychilidae

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INTRODUCTION

Gastropoda is one of the most important groups of Mollusca that has successfully overrun most of the continent (Koudenoukpo *et al*., 2020). They may be found in a wide range of environments across the world, ranging from a defined aquatic environment to a more indeterminate terrestrial one (Kappes & Haase 2012; Ng *et al*., 2013; Vermeulen *et al*., 2015; Effendi *et al*., 2021; Al-Asif *et al*., 2022). It was found in aquatic habitats, such as lakes, rivers, marshes, streams, reservoirs, drainage, and other seasonal water bodies, among other places (Watson & Ormerod, 2004; Hill *et al*., 2016; Al-Asif *et al*., 2021).

The word "stream" is often used to refer to a small channel of freshwater that contains moving water (Doyle & Bernhardt, 2011; Lintern *et al*., 2018; Riley *et al*., 2018). Freshwater streams may be divided into two categories: natural and artificial. While it's obvious that the narrow canal was discovered in the wild, the majority of natural stream definitions include continuous streams in which water flows continuously from the high altitudes of our continental system until it reaches the main destination or low-altitude continental water such as the ocean. Unnatural streams, on the other hand, were created by humans. Furthermore, some of the streams are connected to larger natural bodies of water, such as lakes or rivers, through which they flow (Reddy *et al*., 2018).

Because of the frequent changes in physical perspective that occur in stream ecosystems from early to late in the season, there will be a variety of different wildlife habitat types present, which will have an impact on the diversity richness and species abundance in both freshwater

and marine ecosystems (Elosegi *et al*., 2010; Gebrekiros, 2016; Ali *et al*., 2019; Thushari & Senevirathna, 2020). Other than that, freshwater environments are classified into two major categories which are known as lentic and lotic ecosystems. Lentic environments are used to characterize standing continental water ecosystems (Leandrini *et al*., 2008). Besides, lotic environments are used to characterize better irrigation continental environments (Buffagni *et al*., 2010; Buffagni, 2021). Throughout all habitats, abiotic factors such as temperature, pH, alkalinity, density, light, and other freshwater parameters play an important role in aquatic ecosystems (Paturej *et al*., 2017; Hamid *et al*., 2020). However, some of the freshwater environments will not have precisely the same biotic influences, it depends on the ecosystems that rely on multiple abiotic factors within the biome (Woodward *et al*., 2010; Havel *et al*., 2015).

Taxonomic identification always depends on the study of form and morphology (Jost, 2017). Despite recent improvements and evolution in genetics, morphological identification is mostly used by researchers for identifying gastropod groups and classifying species (Hamli *et al*., 2020b). Morphometric methodologies were originally developed to investigate just form and they may be used for non-biological applications (Lawing & Polly, 2010; Doyle *et al*., 2018; Liuti & Dixon, 2020). Morphometric is just a quantitative way of resolving form variations that have often attracted researchers' attention (Cooke & Terhune, 2015; Hallgrimsson *et al*., 2015). However, recent morphometric software has similar advantages when applied to the study of form but also has other identification features like patterns, textures, and others (Arnqvist & Mårtensson, 1998). In morphometric investigations, the crucial question is usually more theoretically connected to how and what we analyze than to how we approach it statistically.

There are fewer studies conducted by researchers on the diversity of freshwater Mollusca in Malaysia, especially in Malaysian Borneo (Ng *et al*., 2017; Al-Asif *et al*., 2021; Hamli & Al-Asif, 2021; Al-Asif *et al*., 2022). In Sarawak, most of the research focuses on the diversity of marine and brackish gastropods (Raven, 2001; Raven & Vermeulen, 2006; Vermeij & Raven, 2009; Raven, 2016; Raven & Recourt, 2018; Al-Asif *et al*., 2020; Hamli *et al*., 2020a, 2013, 2012; Idris *et al*., 2021). Meanwhile, there are few studies on the variety and distribution of freshwater gastropods being performed in Sarawak, with the majority of studies concentrating on marine and brackish gastropods (Shabdin & Alfred, 2007; Shabdin & Hidir, 2008; Shabdin, 2010; Shabdin *et al*., 2014; Zakirah *et al*., 2019). According to actual statistics, the total number of undiscovered species of mollusks is as high as 240,000 comprising both marine and freshwater (Costello *et al*., 2012). This condition is worsened because of a lack of comprehension, conservation, and management of freshwater gastropod diversity in Malaysia, especially in Sarawak. Considering the knowledge gap, the current investigation was carried out to determine freshwater gastropod populations and their diversity from the selected stream Betong division.

MATERIALS AND METHODS

Study location

The study was conducted in the Betong division which comprised 3 sampling stations that had been selected (Figure 1; Table 1). Sampling point 1 (N 01°36'31.5", E 111°41'58.7") was located in Penebak, Layar (Figure 2a). Sampling point 2 (N 01°36'27.3", E 111°42'13.6") was Sungai Nanga Tiga, Layar which was located at the same place but the origin of the stream was different while both streams flowed to Batang Layar, Betong. The sampling point 3 (N 01°46'39.4", E 111°28'27.4") was located at the Sungai Kabo (Figure 2b).

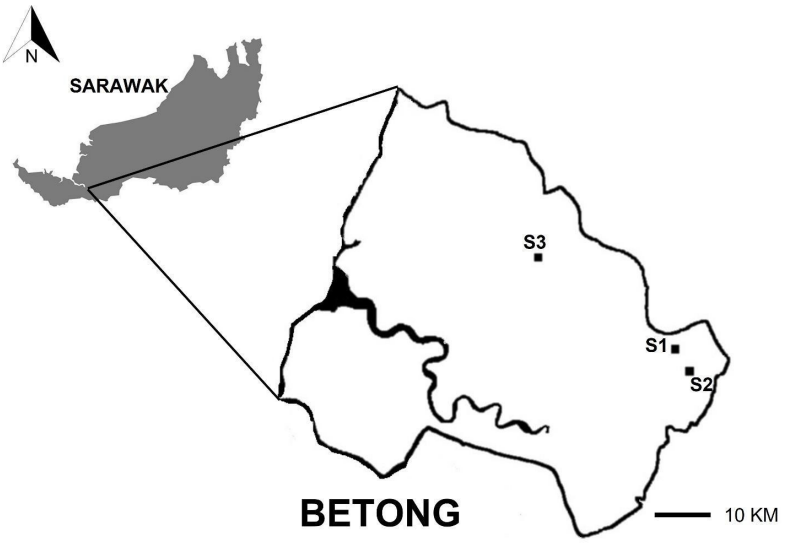

Fig. 1. Freshwater gastropod sampling stations in Betong, Sarawak.

Table 1. The location and coordination of the study sites

Stations	Locations (type)	District	Coordinates
S1	Stream/River	Betong	N 01°36'31.5", E 111°41'58.7"
S2	Stream/River	Betong	N 01°36'27.3", E 111°42'13.6"
S3	Stream/Waterfall	Betong	N 01°46'39.4", E 111°28'27.4"

Fig. 2. a) The shallow stream in Sungai Penebak, Betong, Sarawak, b) Specimens collecting method in Sungai Kabo, Betong, Sarawak

Field sampling technique

At each sampling site, a 50 m sampling transect was laid on the riverbank. Once it's set up, the existing specimens were collected from each sampling point and preserved in the zip bags for species identification. The technique of collecting freshwater conspicuous gastropods was simply to grab them using our hands from the ground and along the riverbank (Irma & Sofyatuddin, 2012). Gastropods that attached to vegetation and floating debris also collected slowly to avoid the destruction of their habitats.

Morphological study

Collected samples were taken to the laboratory for cleaning and visceral mass removal. The study of the shell patterns and measurement was conducted for species identification. The gastropod shells' total length (TL), shell width (SW), aperture length (AL) and aperture width (AW), body whorl (BW), and spine length (S) were measured using Mitutoyo's digital caliper with ±0.1 mm deviation using standard measurements (Figure 3).

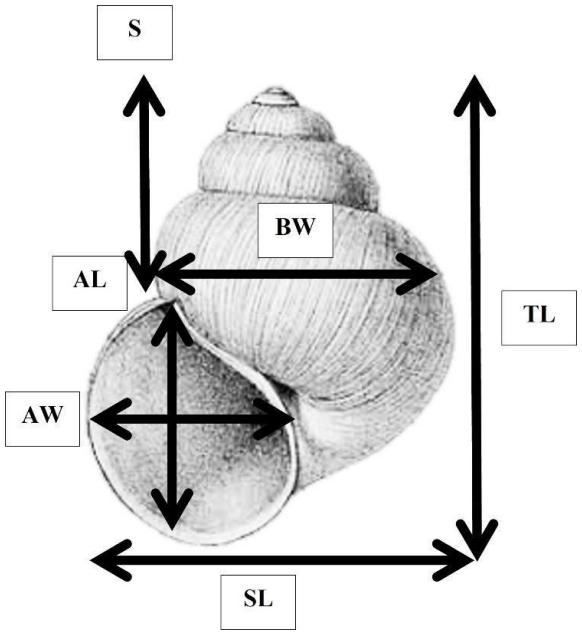

Fig. 3. Shell measurement of collected gastropods.

All of the specimens were identified based on their characteristics followed by Köhler and

Glaubrecht (2001), Köhler and Glaubrecht (2005), Hamli *et al*. (2012), Hamli *et al*. (2020b), Ng *et al*. (2017), Vinarski *et al*. (2017), and other sources that focusing and related on freshwater species. Next, the specimens were photographed using a smartphone (Realme C2) from the aperture and abapertural view.

Statistical analysis

The data of the total number of individuals and the species were tested for the Shannon-Weiner diversity index (H') (Shannon & Weaver, 1949), Pielou's evenness index (J') Pielou (1966), and Margalef's richness index (D) (Margalef, 1958) using Paleontological Statistics (PAST) version 4.10.

RESULTS

Diversity of Gastropod faunal in the study locations

A total of 5 species of Gastropoda fauna were recorded from four orders and four families that were collected from 3 sampling stations in the Betong division (Table 2). During the study, a total 234 of individuals were collected from the sampling stations.

Table 2. The location and coordination of the study sites

			Sampling Stations		
Order	Family	Species	S1	S2	S3
Architaenioglossa	Ampullariidae	*Pila ampullacea* (Linnaeus, 1758)	+	+	-
Neogastropoda	Nassariidae	*Clea nigricans* A. Adams, 1855	+	+	+
[unassigned] Caenogastropoda	Pachychilidae	*Brotia costula (*Rafinesque, 1833)	+	+	+
		Sulcospira pageli (Thiele, 1908)	+	+	+
Cycloneritida	Neritidae	*Vittina pennata* (Born, 1778)	-	-	+

#Indicator: Present (+) Absence (-)

Description and morphometric characteristics of investigated gastropod

Order: Architaenioglossa
Family: Ampullariidae
Species: *Pila ampullacea* (Linnaeus, 1758)

External morphology: It has a white or purplish-white lip, yellowish-orange apertural lips, and banded shells. They have the pinkish-white color of the nacre of the operculum and the well-rounded, globose-shaped shell. Transverse striae patterned along BW. 3 layers of sutures. Absence of AX. Periostracal hair on BW. The second layer of suture and BW cracked. Dark brown shell color (Figure 4).

Shell morphometric: Usually large, TL around 63 to 64 mm, body whorl is 51 to 52 mm. Collected *P. ampullacea* spine length is 15 mm. SW and AL 48 to 59 mm; lastly, the aperture width is around 28 to 29 mm.

Distribution: Upper stream in Sungai Penebak and Sungai Nanga Tiga, Betong.

Habitat: Swamps, drains, and ponds, as well as streams and rivers, are all places where they can be found. The combination of lungs and gills reveals an adaptation to oxygen-depleted aquatic conditions common in marshes and shallow water. Their lungs have been shown to be quite beneficial in surviving in these extreme conditions.

Order: Neogastropoda
Family: Nassariidae
Species: *Clea nigricans* A. Adams, 1855

External morphology: It has a white or brownish inner lip, white with a black line apertural, and outer lips and shells. They have the brown-white color of the operculum and oval or conical-shaped shell. Presence of some fine straie patterned along BW. The inner siphonal notch is white with a rough surface, thick at the edge. Cracked on Apex. Lastly, the shell color was dark greenish (Figure 5).

Shell morphometric: Relatively small size of shell, TL around 24 to 25 mm, body whorl is 18 to 19 mm. Spine length is 6 to 7 mm. Shell width and aperture length 15 to 17 mm. Lastly. The aperture width is around 7 to 8 mm.

Distribution: Upper stream in Sungai Kabo, Sungai Penebak, and Sungai Nanga Tiga, Betong.

Habitat: They are often present in riverbanks and sediment along fast-flowing water streams and rivers during the study.

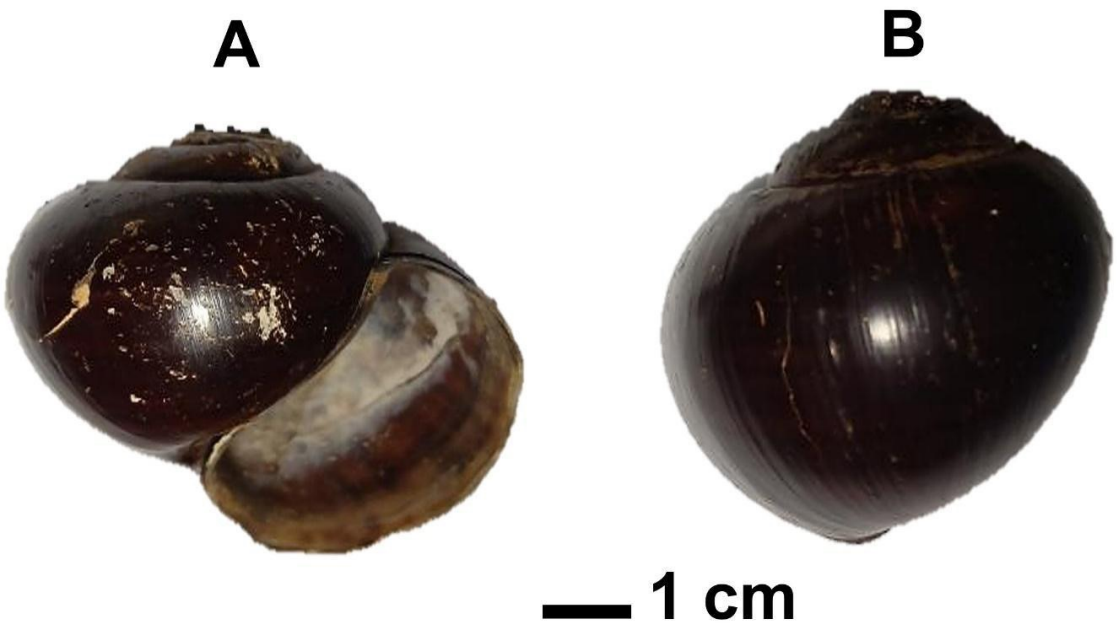

Fig. 4. *Pila ampullacea* (Linnaeus, 1758). A: Ventral view; B: Dorsal view

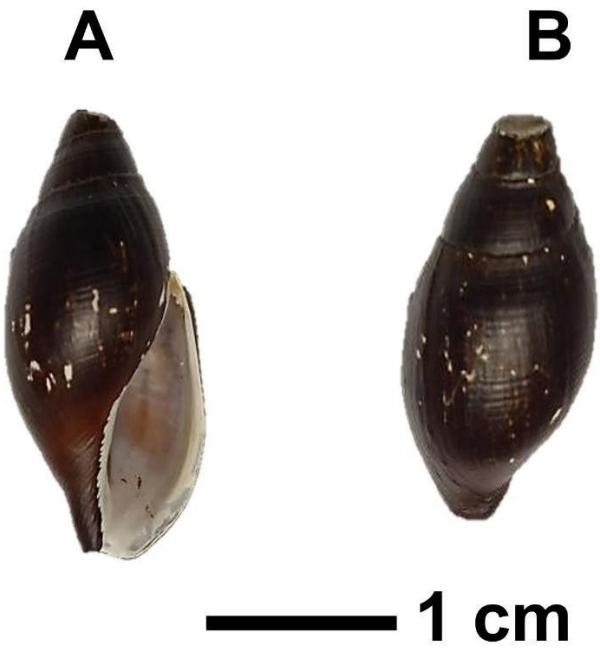

Fig. 5. *Clea nigricans* A. Adams, 1855. A: Ventral view; B: Dorsal view

Order: [unassigned] Caenogastropoda
Family: Pachychilidae
Species: *Brotia costula* (Rafinesque, 1833)

External morphology: Slightly large and has a rough shell surface and solid, pyramidal torn on the BW (Paralectotype MCZ 221841), frequently eroded, six to seven convex on the rounded whorls. It has basal spiral ridges. It appears in brown and dark color. The aperture is wide, and the lip and outer lips are white, well-rounded whorl after the third. Cracked on AX (Figure 6).

Shell morphometric: The total length of the shell is around 42 to 43 mm, body whorl is 21 to 22 mm. Spine length is 26 to 27 mm. Shell width is 19 to 20 mm and the aperture length is 14 to 16 mm; lastly, the aperture width is around 30 to 31 mm.

Distribution: Upper stream in Sungai Kabo, Sungai Penebak, and Sungai Nanga Tiga, Betong.

Habitat: They are often present in riverbanks and sediment along fast-flowing water streams and rivers during the study. They were also found attached to the driftwood in slow motion on the riverbank.

Fig. 6. *Brotia costula* (Rafinesque, 1833). A: Ventral view; B: Dorsal view

Species: *Sulcospira pageli* (Thiele, 1908)

External morphology: Slightly large and has a smooth shell surface along the BW, It has 5 to 7 whorls. The shell consists of spiral striae. It appears in brown and dark color. Axial ribs are present in the BW. The aperture is oval-shaped and the angular inner is white. The shape of the first whorl is more flattened compared to the second and third which is more rounded (Figure 7).

Shell morphometric: The total length of the shell is around 48 to 49 mm, body whorl is 22 to 23 mm. The Spine length is 25 to 26 mm. Shell width is 18 to 18 mm and the aperture length is 17 to 18 mm; lastly, the Aperture width is around 10 to 11 mm.

Distribution: Riverbank in Sungai Kabo, Sungai Penebak and Sungai Nanga Tiga, Betong.

Habitat: The species are often present under the dead leaves and burring themself sediment along fast-flowing water streams and rivers during the study. They were also found attached to the driftwood in slow motion in Sungai Nanga Tiga and Sungai Kabo.

Fig. 7. *Brotia pageli* (Thiele, 1908). A: Ventral view; B: Dorsal view

Order: Cycloneritida
Family: Neritidae
Species: *Vittina pennata* (Born, 1778)

External morphology: The spire is low, the body whorl inflated, and the full length of the shell is linked below with the suture. The shell surface is smooth with the growth lines visible. Shell surface covered with a blackish color at the base, BW yellow patterned with black triangular along the shell. The aperture is D-shaped, and the outer lips are yellow and present on saw-type teeth. Smooth interior with no dentition; Inner lips are white-yellowish (Figure 8).

Shell morphometric: The shell is a medium-sized, elongated-ovoid shell, 31 mm in length.

Distribution: Collected in a small cascade in Sungai Kabo.

Habitat: The species can be found attached to the driftwood or rocks in fast fast-flowing continent.

Diversity indices of available gastropods in the stream ecosystem

Number of species

A total of five Gastropoda species were recorded from all three stations. Where stations 1 and 2 comprised of *Pila ampullacea* (Linnaeus, 1758), *Clea nigricans* A. Adams, 1855, *Brotia costula* (Rafinesque, 1833), and *Sulcospira pageli* (Thiele, 1908) species, while station 3 comprised of *Clea nigricans* A. Adams, 1855, *Brotia costula* (Rafinesque, 1833), *Sulcospira pageli* (Thiele, 1908) and *Vittina pennata* (Born, 1778) species respectively (Figure 9).

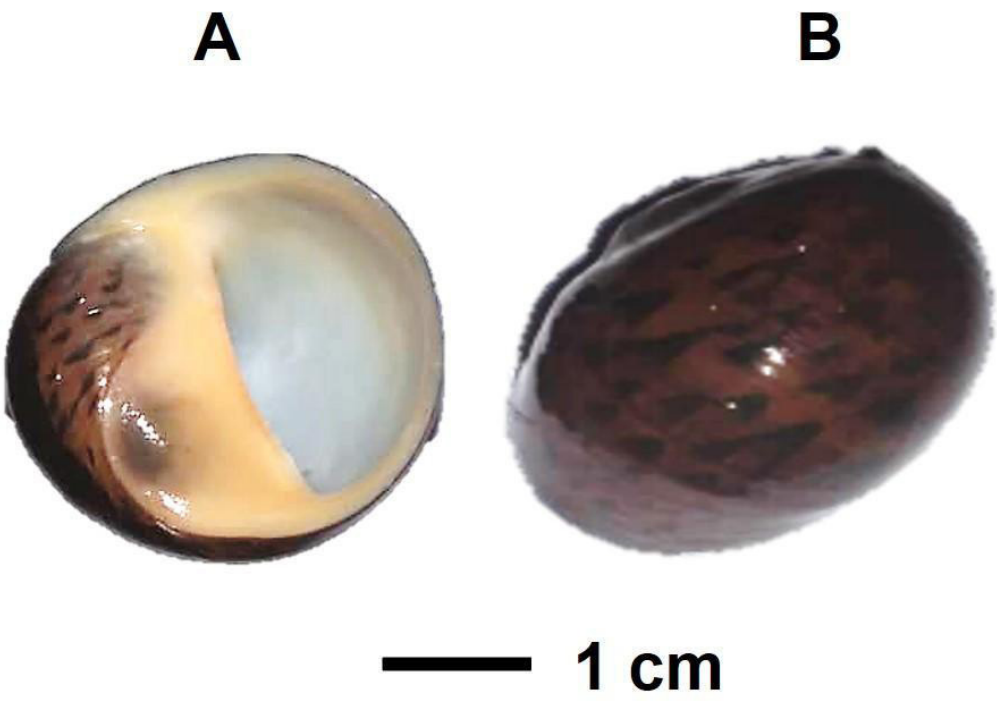

Fig. 8. *Vittina pennata* (Born, 1778). A: Ventral view; B: Dorsal view

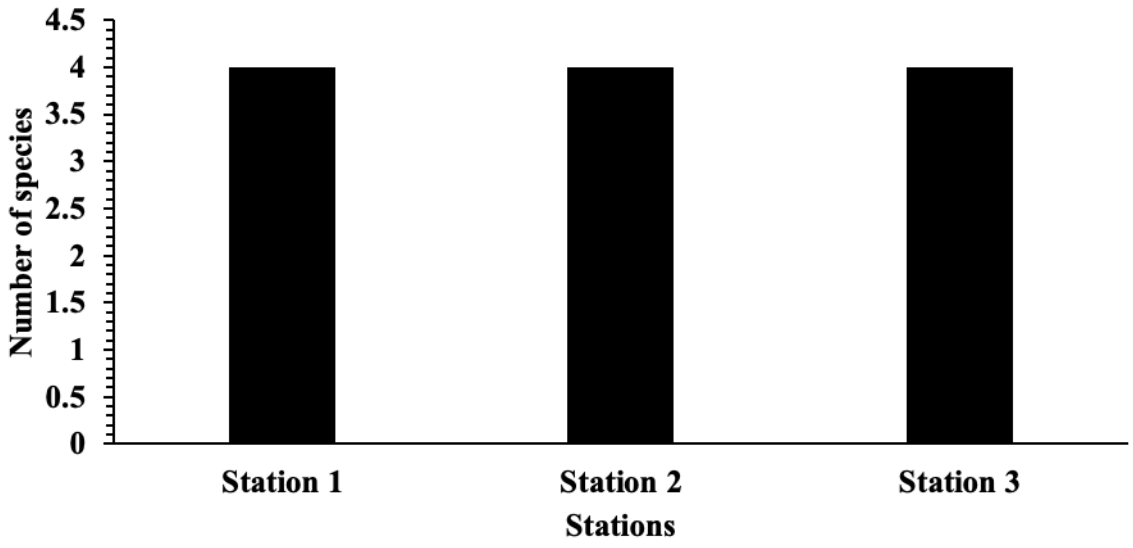

Fig. 9. Number of species in different stations.

Number of individuals

A total 234 of individuals were collected from all sampling stations. The station that had the highest number of individuals was Sungai Nanga Tiga which had 87 individuals (station 2). Followed by Sungai Penebak recorded 76 individuals (station 1) and Sungai Kabo recorded 71 individuals (station 3) (Figure 10).

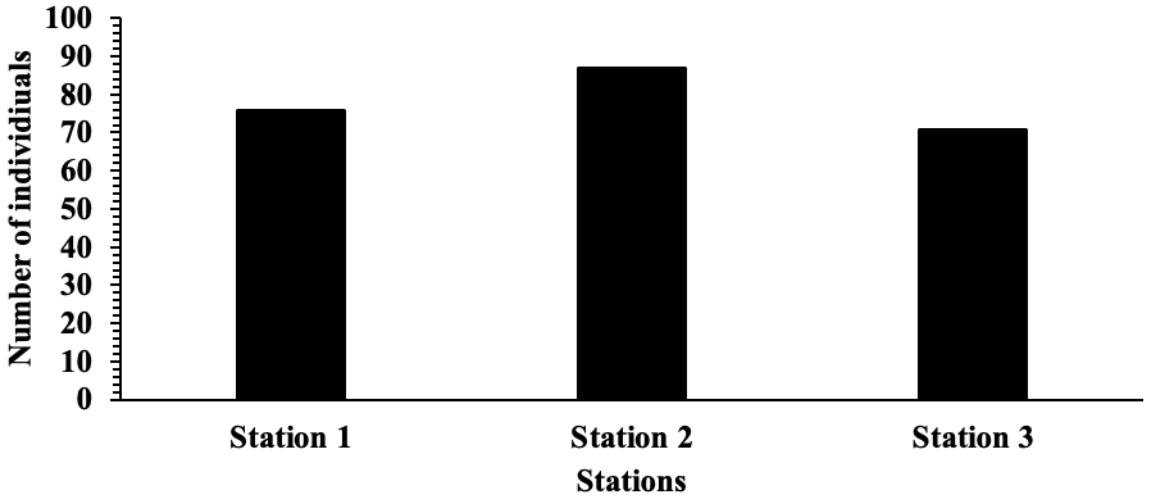

Fig. 10. Number of individual shells in different stations.

Diversity indices

The present study indicated that Station 3 comprises the highest value for Shannon-Weiner's diversity index, Pielou's evenness index, and Margalef's richness index. Station 3 showed Shannon-Weiner's diversity index value of 1.142, followed by station 2 (1.035) and station 1 (0.9948) (Figure 11). Pielou's evenness index indicated a high value was 0.78 (station 3) followed by 0.7034 (station 2), and 0.676 (station 1). The richness of the freshwater gastropod showed the lowest value from station 2 with a value of 0.6718, followed by station 1 (0.6927) and station 3 (0.7038). The freshwater gastropod richness was lowest at station 2, with a value of 0.6718, followed by station 1 (0.6927) and station 3 (0.7038).

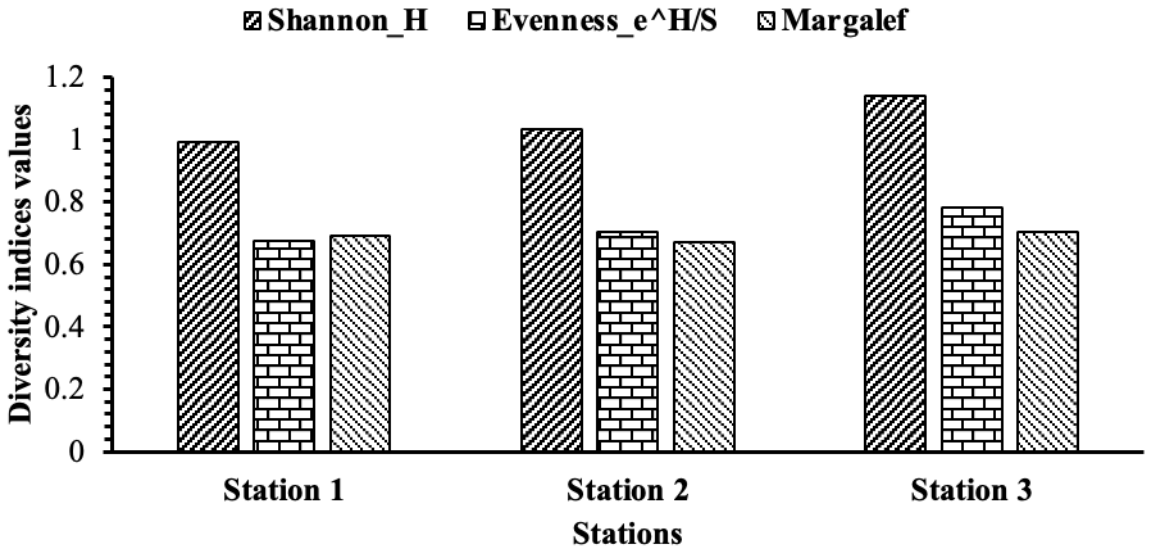

Fig. 11. Diversity indices of shells found in different stations.

DISCUSSIONS

A total of five species of Gastropoda were recorded from this current research area in Betong. The common species was from the family Pachychilidae such as *Brotia pageli* followed by *Clea nigricans* from the family Nassariidae and these two species were found in higher numbers in all stations. The species' presence in all stations was more than 20 individuals. Five species of gastropods were recorded from all the sampling stations belonging to four families which were Ampullariidae, Nassariidae, Pachychilidae, and Neritidae in the freshwater stream of Betong. *P. ampullae* and *Vittina pennata* were distributed irregularly from the sampling stations. The number of families found in the present study is

less compared to the previous study which study covered many localities of Sarawak (Hamli *et al*.,2012; Hamli *et al*., 2013; Hamli *et al*., 2020a).

The low number of species found may be due to certain factors such as water quality and the species' habitat requirements. McClain and Rex (2001) discovered that the amount of dissolved oxygen in the water would have a substantial impact mostly on the body composition of deep-sea Gastropoda. Other than that, the pH also has a significant impact on gastropod life. Bibby *et al*. (2007) discovered that acidic water reduces shell thickness and boosts metabolism but Harvey *et al*. (2016) stated that these gastropods raise energy requirements to reduce cell size while increasing body size. According to Sokolova and Pörtner (2003), Gastropoda in tropic water bodies prefer water temperatures between 28-30°C, however, metabolism can occur at temperatures ranging from 25 to 40°C. According to Garg *et al*. (2009), rising water temperature activates the organic materials in the bottom. Matsukura *et al*. (2009) discovered that cold temperatures can affect the cells and damage the organs of freshwater gastropods.

However, few species were found, and this might be due to limited sampling procedures. Are there other species in unexplored places? This might be this is one of the factors that limits the number of freshwater gastropod species in the sampling station (Al-Asif *et al*., 2022). In addition, all the research areas are close to residential areas where some residents or villages consume these gastropods as their food source. *B. pageli* is commonly consumed by the residents, however, it shows no significant effect on the abundance of the species. Back to the factors that determine the number of species present, all species namely *B. costula*, *B. pageli,* and *Clea nigricans* were discovered in the same habitat where they are attached to rocks and plants of riverbank areas. According to Köhler and Glaubrecht (2002), *B. pageli* usually inhabits clear streams with rocky and sandy substrates. During the study, *V. pennata* was found attached to a rock at a small cascade with fast fast-flowing continent. According to a previous study by Chen and Zhang (2018), this freshwater gastropod species *V. pennata* inhabits fast continental and also be found near the river mouth when tidal occurs.

The current study suggested the Shannon-Weiner's diversity index of Gastropoda available in streams was between 0.9948 and 1.142; while Pielou's evenness index ranged between 0.7034 and 0.676; and the Margalef's richness index was between 0.6718 and 0.703 among different sampling location. Similar studies from different locations around the world reported the relevant diversity indices (Sharma *et al*., 2013; Galan *et al*., 2015; Velasco *et al*., 2018; Weerakoon *et al*., 2021).

CONCLUSION

The freshwater gastropod of Betong was lowly diverse in terms of richness but had a heterogeneous abundance. However, there seems to be no evidence of stream deterioration in Betong Division, but with the size of the population of the residential keep increasing each decade and the agricultural expansions in that region, it is essential to take action to conserve the aquatic ecosystems and aquatic species. Benthos species are used as the ecological indicator of any ecosystem, and this data might be helpful to assess the environmental and ecological condition of these stream habitats. Further studies on the interrelation between biotic Gastropoda and the abiotic factors can be conducted to evaluate the interaction between them. Along with trophic structures, ecological niche studies on the Gastropoda species in different streams in different locations are recommended.

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ETHICAL STATEMENT

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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