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CORRELATION BETWEEN BENTHIC MACROINVERTEBRATE DISTRIBUTION AND SUBSTRATE COMPOSITION IN SELECTED RECREATIONAL RIVERS IN KELANTAN, MALAYSIA

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Abstract: This study was carried out to determine the correlation between benthic macroinvertebrate and substrate composition in recreational rivers in Bukit Bakar, Jeram Pasu, and Lata Mengaji. Pebble count method and Surber net were used for substrates and benthic macroinvertebrate data collection, respectively. D_{50} of substrates compositions was calculated using the pebble count data and correlated with benthic macroinvertebrates compositions by using Pearson correlation. The highest D_{50} measured was at Lata Mengaji (Station 5) with 120.11mm and the lowest D_{50} at Jeram Pasu (Station 5) with 10.82mm. Therefore, results showed the different richness, composition, and distribution of families between the three sites. Athericidae, Chironomidae, Elmidae, Euphaeidae, Helodidae, Heptageniidae, Leptophlebiidae, Platystictidae, Psephenidae and Simuliidae show a significant difference between sites. However, among all of these families, only families Psephenidae and Elmidae had the highest correlation with D_{50} (p-value<0.05). This was concluded that the substrate size compositions and arrangement are factors that influence the benthic macroinvertebrate distribution in rivers.

Keywords: Pebble count method; substrates; macroinvertebrates; Bukit Bakar; Jeram Pasu; Lata Mengaji;

Introduction

Benthic macroinvertebrates can be categorized into functional feeding group (FFG) according to their functional feeding behavior such as predator, grazer, filter, collector, scraper, and shredder (Suhaila & Che Salmah, 2014). Each FFG has its own function in the aquatic ecosystems, which indirectly helps in maintaining ecosystem quality (Doi, 2009; Suhaila & Che Salmah, 2014). Besides that, some order of benthic macroinvertebrates also play roles in food web chain and act as fish food (Shabdin, 2010). However, the tolerance of these organisms toward environmental change is different due to their morphological diversity (Kamsia *et al.,* 2007). Theoretically, being an important component of freshwater ecosystems, benthic macroinvertebrates can be good bio-indicators to understand ecosystem structure and function (James *et al.*, 2006; Zhao et al., 2013). Therefore, river monitoring indices such as Family Biotic index (FBI), Hilsenhoff Biotic Index (HBI), Average Score Per Taxon (ASPT), and Biological Monitoring Working Party (BMWP) were developed based on benthic macroinvertebrate data (Li *et al.,* 2010; Tasneem & Abbasi, 2012; Ahmad *et al.,* 2015). Bukit Bakar, Jeram Pasu, and Lata Mengaji are three recreational rivers in Kelantan that have cool and fast-flowing water. However, it can be seen by naked eyes that the substrates size composition and distribution in these rivers are different. This might lead to differences in distribution and composition of benthic macroinvertebrates. This has been discussed by Wan Mohd Hafezul *et al.* (2016) that type of substrates was one of the factors that cause variation of Ephemeroptera species in the river ecosystem. Substrates were believed to be one of the abiotic factors that trap food (Wan Mohd Hafezul *et al.,* 2016), forming river microhabitat (Mohmad *et al.*, 2015) and benthic shelter for macroinvertebrates (Ahmad *et al.,* 2013). Therefore, this study was conducted to identify the differences in benthic macroinvertebrates' composition of between rivers and to understand the correlation between the benthic macroinvertebrates' and substrates size composition in these rivers.

Materials and Methods

Study site

This study focused on recreational rivers since there are no data on benthic macroinvertebrates collected in this type of rivers in Kelantan. Three famous recreational rivers in Kelantan were selected in this, study namely Bukit Bakar Recreational Forest in Machang, Lata Mengaji in Selinsing, and Jeram Pasu in Pasir Puteh (Figure 1). Basically, the study areas were selected according to the accessibility of the rivers and possibility of pollution, especially through the disposal of solid waste and river modification. However, the variety of substrate pattern along these rivers were the most important reason as a variety of substrates were needed for comparison and correlation with the composition of benthic macroinvertebrates'. Table 1 shows the coordinates and site habitat descriptions.

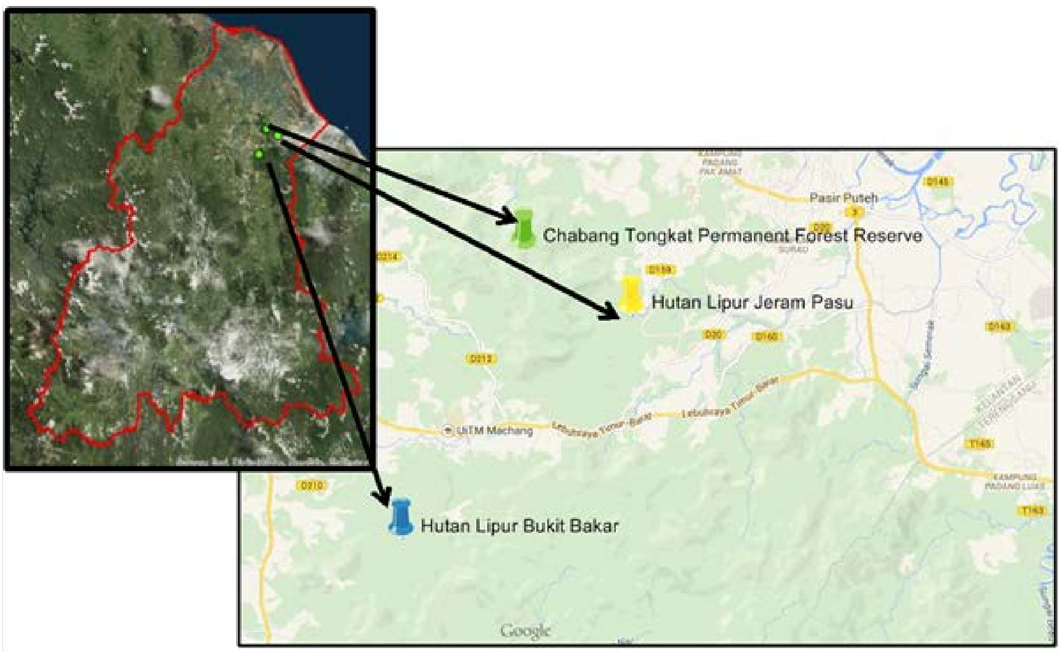

Figure 1. Three selected study sites in Kelantan (inset picture from Google Map); comprising Hutan Lipur Bukit Bakar, Hutan Liput Jeram Pasu, and Chabang Tongkat Permanent Forest Reserve (magnified map generated from ArcGIS 10.0).

Table 1. Site coordinates and description of canopy covered

No.	Site	Coordinates	Habitat description
1	Bukit Bakar	5°43'22.1"N 102°15'27.8"E	Width: 5m - 6.6m Depth : 0.13m-0.18m Velocity : 0.1m/sec Canopy covered : fully and partially shaded
2	Jeram Pasu	5°47'39.3"N 102°20'12.7"E	Width: 2.4m - 7.2m Depth : 0.11m - 0.23m Velocity : 0.1m/sec -0.3m/sec Canopy covered : fully and partially shaded
3	Lata Mengaji	5°49'47.5"N 102°17'25.6"E	Width: 2.5m - 8.8m Depth : 0.19m - 0.21m Velocity : 0.2-0.7m/sec Canopy covered : fully shaded

Field sampling

The Surber net was used to collect benthic macroinvertebrates on a five-meter transect line across the stream and diagonally upstream following guidelines stated in the Kentucky Division of Water (KDOW, 2011). Five stations were identified at every sampling site and three replicates were taken for each station. Samples collected were placed in a zipper bags and preserved using 80% ethanol. Substrate composition was determined by using pebble count method (Wolman, 1954) with a minimum of 100 pebble measurements. These were measured using a measuring tape and digital calipers in mm and categorized using standard Wentworth size classes (Bevenger *et al.,* 1995).

Sample analysis

Benthic macroinvertebrates were sieved through a 500 μm mesh sieve and any organisms retained on the sieve were sorted and collected using forceps. Benthic macroinvertebrates were identified up to family level using a stereo microscope, following available identification keys such as Annelise & Gabriel (2002), Yule & Yong (2004) and Sangpradub *et al.* (2006). Then, benthic macroinvertebrates were counted and preserved in a universal bottle per a replicate sample with 75% ethanol.

Data analysis

The pebbles were classified into six categories, namely, gravel, cobble, boulder, silt, sand, and bedrock (from <2mm until >1024mm) based on the intermediate axis measurement (Tucker, 2012 and Zhao *et al.,* 2013). Then, D50 of substrate composition was calculated using the pebble count data and the benthic macroinvertebrates were totaled by family and recorded. Substrates and benthic macroinvertebrate data were tested for normality using a Shapiro-Wilks test to check for assumptions of bivariate normality (McDonald, 2014), whereas the Pearson Correlation was used to determine the correlation composition between benthic macroinvertebrates and substrates'.

Results and Discussion

Substrate distribution

The results showed that all sites were dominated by three categories of substrates, namely, gravel (2.01-64.00 mm), cobble (64.01-256.00mm) and boulder (256.00-1024.00mm). However, there were some differences in substrate D50 values observed between these rivers (Bukit Bakar = 59.76mm, Jeram Pasu = 22.45mm, and Lata Mengaji = 112.07mm). These were due to the significant difference in compositions of other substrates categories between the sites and stations, which are silt (0-1.00mm), sand (1.01-2.00 mm) and bedrock (>1024.00mm) (Bevenger *et al.,* 1995). Based on the data collected, Bukit Bakar and Lata Mengaji did not have substrates in the sand category compared to Jeram Pasu. However, this does not mean that there was no sand in these rivers as pebble count is a measure of the percentage of fine sediment calculated from at least 100 random substrates. Hence sand might be located between or under the other substrates. Figures 2, 3 and 4 show the pattern of substrate composition between stations at all sites. Table 2 indicate that substrate composition at all sites was normally distributed.

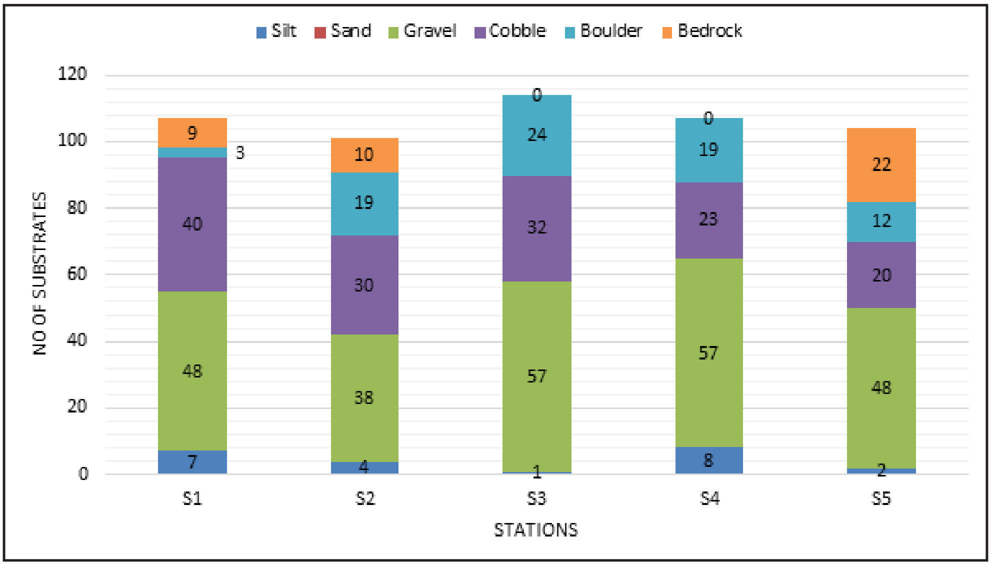

Figure 2. Frequency of pebbles in Bukit Bakar

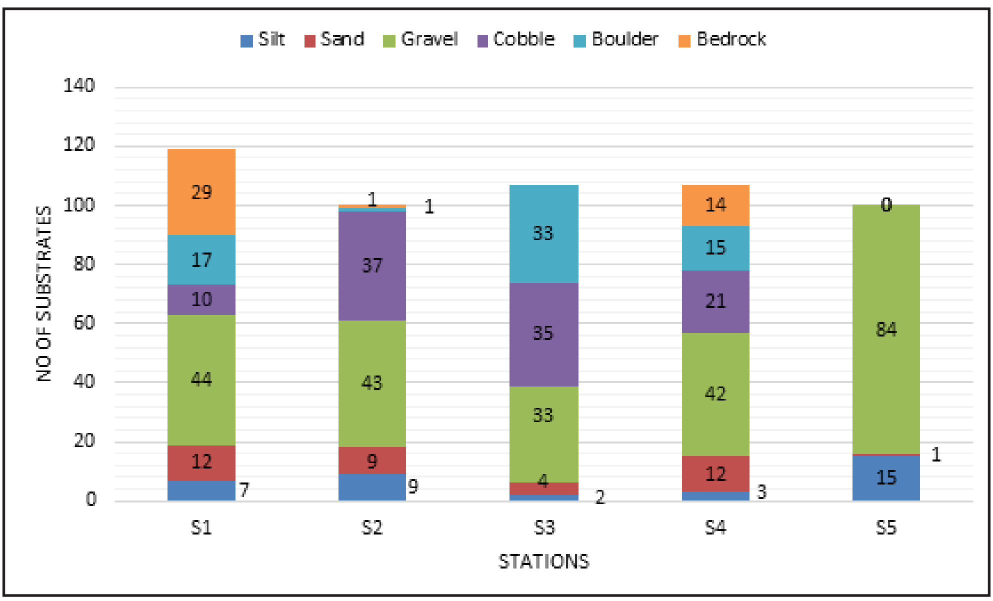

Figure 3. Frequency of pebbles in Jeram Pasu

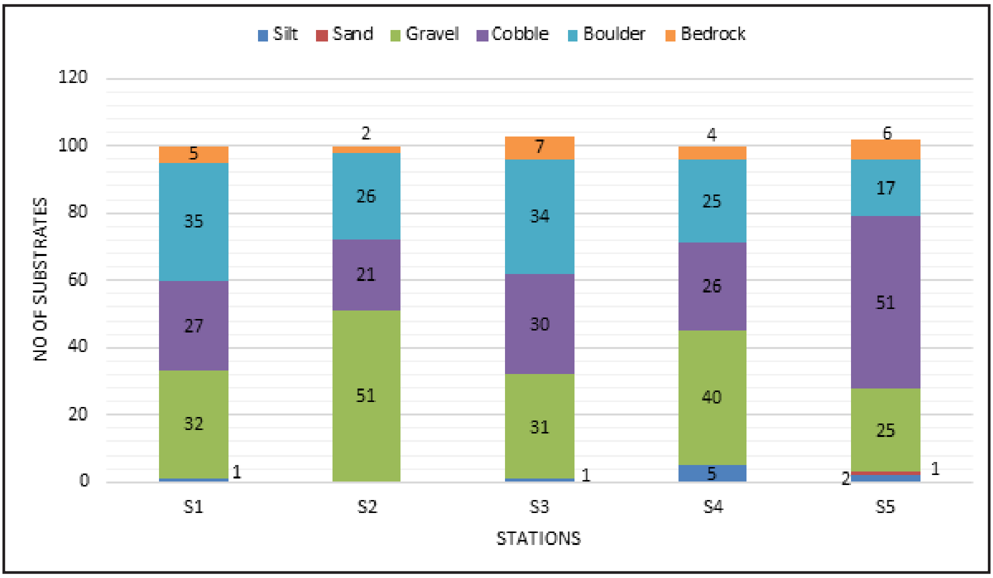

Figure 4. Frequency of pebbles in Lata Mengaji

Sampling Site	Shapiro-Wilk test		
	Statistic	df	p-value
Bukit Bakar	9.11	5	0.473
Jeram Pasu	0.872	5	0.271
Lata Mengaji	0.888	5	0.349

Benthic macroinvertebrate composition

There were 45 families of benthic macroinvertebrates found at all sites, where 38 families were found at Bukit Bakar and 29 families at Jeram Pasu and Lata Mengaji. Table 3 shows the total individual, family, and composition of benthic macroinvertebrates for all sampling sites in this study.

Table 3. The total individual, family, and composition of benthic macroinvertebrates for all sampling sites

No	Families	Bukit Bakar	Jeram Pasu	Lata Mengaji	Total
1	Chironomidae	904	146	92	1142
2	Helodidae	456	68	211	735
3	Elmidae	183	69	313	565
4	Heptageniidae	287	30	75	392
5	Perlidae	98	117	74	289
6	Psephenidae	80	19	178	277
7	Baetidae	132	100	42	274
8-9	Hydropsychidae	98	48	98	244
10	Tipulidae	125	67	13	205
11	Polycentropodidae	97	29	45	171
12	Platystictidae	143	7	7	157
13	Simuliidae	36	97	13	146
14	Leptophlebiidae	67	13	35	115
15	Athericidae	67	0	4	71
16	Ceratopogenidae	17	11	21	49
17	Teloganodidae	12	12	20	44
18	Palaemonidae	9	5	26	40
19	Caenidae	21	6	12	39
20	Euphaeidae	29	1	0	30
21	Veliidae	10	8	5	23
22	Amphipterygidae	7	4	4	15
23	Notonemouridae	1	9	2	12
24	Philopotamidae	2	6	0	8
25	Gyrinidae	4	0	3	7
26	Barbarochtonidae	1	3	0	4
27	Ephydridae	4	0	0	4
28	Gerridae	2	2	0	4
29	Potamonautidae	1	2	1	4
30	Protoneuridae	4	0	0	4
31	Tricorythidae	3	0	1	4
32	Ecnomidae	1	2	0	3
33	Limnephilidae	2	1	0	3
34	Coenagrionidae	2	0	0	2
35	Thiaridae	0	2	0	2
36	Chlorocyphidae	1	0	0	1
37	Culicidae	0	1	0	1
38	Dytiscidae	0	0	1	1
39	Empididae	0	0	1	1
40	Glossosomatidae	1	0	0	1
41	Halipidae	0	0	1	1
42	Hydrophilidae	1	0	0	1
43	Hydroptilidae	1	0	0	1
44	Oligochaeta	1	0	0	1
45	Pleidae	0	0	1	1
46	Tabanidae	0	0	1	1
	Total Individual	2910	885	1300	5095
	Total Family	38	29	29	45

The composition of benthic macroinvertebrates in Jeram Pasu is the less abundant compared to Lata Mengaji although the number of families was found to be similar. The families common at all sites were Tipulidae, Hydropsychidae, Baetidae, Psephenidae, Perlidae, Heptageniidae, Elmidae, Helodidae, and Chironomidae. These families were common benthic macroinvertebrates found in fast-flowing and upstream rivers in Malaysia. However, ten families which were Athericidae, Chironomidae, Elmidae, Euphaeidae, Helodidae, Heptageniidae, Leptophlebiidae, Platystictidae, Psephenidae and Simuliidae showed a significant difference between sites. Mohmad *et al.* (2015) found that these families, except Chironomidae were abundant in areas that have lots of riffles, run and fast flowing runs. However, Wardiatno and Krisanti (2013) mentioned that although chironomids can adapt to the low dissolved oxygen, they thrive in high dissolved oxygenated areas. Besides, of substrate composition influences the turbulence of water flow that leads to a phenomenon well-oxygenated water in the river. On the other hand, Chironomidae are also abundant in shallow and flowing water bodies compared to highly turbid, deep and stagnant water bodies. In this study, the highest abundance of Chironomidae was found at Bukit Bakar and Jeram Pasu.

Even though all sites have fast-flowing, cool and clean water, Lata Mengaji contained a wide range of substrate composition compared to others sites. This might be the reason for the high composition of Elmidae at Lata Mengaji compared to other sites. According to Annelise & Gabriel (2002), Elmidae have legs that are not adapted to swimming making them need stone or hard substrate to cling. Besides, this family of coleopteran needs high oxygen concentration because they cannot breathe atmospheric oxygen. High water flow forming from substrates distribution and compositions was one of the factors to achieve this condition. Shabdin (2010) also mention the rocky bank with vegetation grown also a spot for breeding of some order which also mentioned by Suhaila & Che Salmah (2011) that river substrate was a platform for egg incubation.

Perlidae was a common family of Plecoptera found in fast-flowing, cool and clean water (Ahmad *et al.,* 2015). However, Perlidae was found more abundant at Jeram Pasu (117) instead Bukit Bakar (98) and Lata Mengaji (74). Mohmad *et al.* (2015) showed that Perlidae composition in Sabah was higher in the area with runs and pools composed of sand, gravel, cobbles, pebbles, and bedrock. While Suhaila & Che Salmah (2011) mentioned Plecoptera preferred habitats with more than 25% substrates surrounded by fine sediments such as sand and silts. Besides swimming and running slow, Perlidae also preferred to live among dead leaves and sand (Ahmad *et al.,* 2013). This might be one behavior for a predator to make a hiding space to stalk their prey. Besides that, this type of habitat is also preferred by Diptera which one of Perlidae food availability as a predator (Sangpradub *et al.,* 2006).

Correlation between substrates and benthic macroinvertebrate composition

Several studies found that the composition and distribution of benthic macroinvertebrates were influenced by types of substrates' (Wardiatno & Krisanti, 2013; Scott, 2006). Substrates create the habitat and shelter for several benthic macroinvertebrates. The different distribution and composition of substrate size can create different type of microhabitats that can change the water flow, turbidity and accumulation of debris at the surface of the water (Annelise & Gabriel, 2002; Yule & Yong., 2004). The results of this study were congruent with previous findings where substrate composition influenced the compositions of benthic macroinvertebrates.

The Pearson correlation analysis supported a relationship between benthic macroinvertebrates distribution and substrate composition in Bukit Bakar, Jeram Pasu, and Lata Mengaji. It was observed that Bukit Bakar has the highest correlation value with 0.931 while Jeram Pasu and Lata Mengaji have 0.692 and 0.670 correlation values respectively. These results indicate that the differences in correlation value for both compositions of benthic macroinvertebrates and substrate composition were probably due to the different distribution of substrates, especially in Jeram Pasu and Lata Mengaji. The latter sites were not present of all six substrate size categories (silt, sand, gravel, stone, boulder, and bedrock) as Jeram Pasu had more gravel, while substrates in Lata Mengaji had a balance composition of gravel, cobbles, and pebbles. Less variation among types of substrate size decreases the diversity of benthic macroinvertebrates. Hence, the results are in agreement that variations of substrate do influence benthic macroinvertebrates' compositions in the river (Sharifah Aisyah *et al.,* 2015).

Psephenidae and Elmidae had the highest correlation with D50 (p-value<0.05). This means the family composition were related to the substrate distribution and composition. Elmidae and Psephenidae were abundant at Bukit Bakar and Lata Mengaji compared to Jeram Pasu as there are more pebbles, boulders, and bedrock. This type of substrate composition can form riffles and run with fast-flowing water that generates more oxygen concentration in water which is suitable for this family to survive. Aforementioned, these order of benthic macroinvertebrates were not swimming type organisms as they preferred to cling and crawl stone or hard substance. Besides, correlation analysis showed that Elmidae had 50% significant negative correlation with silt and sand (p-value<0.05) as well as Psephenidae. Whereas, Helodidae and Heptageniidae had 40% negative correlation with sand substrates (p-value<0.05). In contrast, Simuliidae had 80% positive correlation with sand (p-value<0.05). These showed that each family of benthic macroinvertebrates has its own adaptation and habitat preference (Annelise & Gabriel, 2002 and Yule & Yong, 2004). These substrates play an important role in aiding benthic macroinvertebrates to trap food, provide shelter and egg incubation (Suhaila & Che Salmah, 2011). Therefore, in shallow rivers such as a recreational river, the substrates composition is important in maintaining the diversity and ecology of benthic macroinvertebrates.

Conclusion

In conclusion, Bukit Bakar was more abundant with benthic macroinvertebrates compared to Jeram Pasu and Lata Mengaji whereas Bukit Bakar and Lata Mengaji had more diversity of substrates compared to Jeram Pasu as this river had more sand. Overall, all sites showed a high correlation between benthic macroinvertebrate and substrate composition. However, the highest correlation showed for D50 with Elmidae and Psephenidae. The silt and sand compositions also had a correlations with Elmidae and Psephenidae. Moderate negative correlations with sand composition were also detected for compositions of Helodidae, Heptageniidae, and Simuliidae. The correlations were believed to be due to the roles of substrates composition in creating microhabitat that are suitable for benthic macroinvertebrates to survive and adapt. This study also found that benthic macroinvertebrates can be used as sedimentation bio-indicators for recreational rivers as the lower diversity of substrates' type may reduce the compositions and diversity of benthic macroinvertebrates.

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