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Effect of Anthropogenic Activity on Benthic Macroinvertebrate Functional Feeding Groups in Small Streams of West Sumatra, Indonesia

(Kesan Aktiviti Antropogen pada Kumpulan Fungsian Pemakanan Bentik Makroinvertebrata di Sungai Kecil Sumatra Barat, Indonesia)

Jojok Sudarso*, Tri Suryono, Gunawan P. Yoga, Imroatusshoolikhah, Aiman Ibrahim, Laela Sari, Muhammad Badjoeri & Octavianto Samir

Puslit Limnologi-LIPI, Jl. Jakarta-Bogor Km. 46, 16911, Cibinong, Indonesia

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ABSTRACT

Functional feeding groups (FFG) of benthic macroinvertebrates have been used to characterize the condition of aquatic ecosystems, changes in land use, and assess the river health ecosystems. Ranggeh River belongs to a small river that plays a vital role in breeding the native fish of Lake Maninjau (West Sumatra). Agricultural activities and human settlements around the Ranggeh River can threaten life and change the FFG of benthic macroinvertebrates. This study aims to analyze and observe changes in water quality by anthropogenic activities and their impact on FFG benthic macroinvertebrates in a small stream (Ranggeh River). This research was conducted at the Ranggeh River segment from February to August 2019. A sampling of benthic macroinvertebrates was carried out using a Hess sampler on the riffle. This study shows that predators, shredders, and scrapers are still dominant when the Ranggeh River ecosystem is still minimally disturbed by agricultural activities and settlements. However, when agriculture activities and human settlements become more massive, the dominant FFGs are collector-filterers and collector-gatherers. Sedimentation parameters (turbidity and % embeddedness) in the Ranggeh River greatly influence predators, scrapers, and shredders. FFG has excellent potential to be further developed in preparing biocriteria for the effects of agriculture and human settlements.

Keywords: Benthic macroinvertebrates; pollution; sedimentation; tropical; water quality

ABSTRAK

Kumpulan fungsian pemakanan (FFG) daripada organisma bentik makroinvertebrata telah digunakan untuk mencirikan keadaan ekosistem akuatik, perubahan penggunaan tanah, serta menilai kesihatan ekosistem sungai. Sungai Ranggeh merupakan sungai kecil yang memainkan peranan penting dalam jalur migrasi ikan tempatan Danau Maninjau (Sumatera Barat). Aktiviti pertanian dan pemukiman penduduk di sekitar Sungai Ranggeh boleh mengancam kehidupan dan mengubah FFG bentik makroinvertebrata. Penyelidikan ini bertujuan untuk menganalisis dan memerhati perubahan kualiti air oleh aktiviti antropogen dan kesannya terhadapFFG bentik makroinvertebrata di Sungai Ranggeh. Penyelidikan ini dijalankan di segmen Sungai Ranggeh dari Februari hingga Ogos 2019. Persampelan makroinvertebrata bentik telah dijalankan menggunakan alat Hess-sampler di bahagian balan. Kajian ini menunjukkan bahawa apabila ekosistem Sungai Ranggeh masih terganggu pada tahap minimum oleh aktiviti pertanian dan pemukiman penduduk, pemangsa FFG, pencarik dan pengikis masih dominan. Namun ketika aktiviti pertanian dan pemukiman penduduk menjadi lebih pesat, FFG yang dominan adalah pemungut-penapis dan pengumpul-pemungut. Parameter sedimentasi (kekeruhan dan % batu tertanam) di Sungai Ranggeh mempunyai pengaruh yang besar terhadap FFG pemangsa, pengikis dan pencarik. FFG mempunyai potensi besar untuk dikembangkan lagi dalam penyediaan biokriteria untuk kesan pertanian dan pemukiman penduduk.

Keywords: Bentik makroinvertebrata; kualiti air; pemendapan; pencemaran; tropika

Introduction

Benthic macroinvertebrates have important roles in lotic ecosystems, including nutrient cycling, energy flow, and prey for other predators (Moyo & Richoux 2017; Ramirez & Gutierrez-Fonseca 2014; Weliange et al. 2017). In addition, these animals play a role in carbon transfer from primary producers to higher consumers (Wang et al. 2020). The animal community is formed from the interaction of biotic and abiotic factors in spatial and temporal scales. Several important abiotic factors contribute to communities formation: flow regime, riverbed geomorphology, land use, riparian zone, presence of large wood, debris, substrate, and water quality (Weliange et al. 2017). Fu et al. (2015) and Mangadze et al. (2017) mention that Land-use practices in river basins can change hydrological characteristics, substrate availability, water quality, and complexity of interacting biotic and abiotic factors that regulate functions and attributes of benthic macroinvertebrate communities. These animals also can be widely distributed, relatively sessile in water, and have high diversity (Gutierrez-Fonseca 2014). With the various advantages of the animals mentioned above, the biota is suitable for evaluating disturbances in aquatic ecosystems, commonly known as bioassessment (Weliange et al. 2017).

Studies of macroinvertebrate FFG can provide information about the balancing of feeding strategies (food acquisition) in the benthic community (Wang et al. 2020). The use of FFG in lotic ecosystems has been used to characterize ecosystem conditions (Menezes et al. 2010), changes in land use (Mangadze et al. 2017; Nautiyal & Mishra 2013), riparian vegetation (Wang et al. 2020), as well as the health of river ecosystems (Yoshimura et al. 2006). The composition of FFG in the community can respond to environmental gradient conditions and changes in river ecosystem functions such as degradation and transport of organic matter (Leslie & Lamp 2016). The classification of FFG is based more on the adaptation process or strategy in obtaining food than what is eaten in the form of organic matter (Cummins & Klug 1979; Ramirez & Gutierrez-Fonseca 2014). In general, FFG of benthic macro-invertebrates is divided into four types: shredders, scrapers, gatherers, and filterers (Cummins & Klug 1979; Fu et al. 2015). However, some macroinvertebrate species may be generalists and fit into more than one type of feeding group (Cummins & Klug 1979).

Biological metrics from FFG can be developed as biological indicators, so they are often involved in the preparation and assessment of ecosystem health (Bhawsar, Bhat & Vyas 2015; Wang et al. 2020). The relative abundance of the FFG matrix may reflect anthropogenic influences on lotic ecosystems (Cummins, Merritt & Andrade 2005; Merritt et al. 2002). Incorporating FFG and other biotic indices such as in multimetric models can be more accurate and comprehensive in reflecting pollution status (Barbour et al. 1996), understanding the relationship between habitat and aquatic fauna (Townsend, Scarsbrook & Dolédec 1997), as well as ecosystem function (Ferreira, Encalada & Graça 2012).

The Ranggeh River is the inlet of Lake Maninjau in West Sumatra, Indonesia. This river is relatively small in size with a width of 1-1.5 meters with a depth of between 20-50 cm. The role of the Ranggeh River is critical in clouding the route of the lake's native fish, such as *Rasbora maninjau, Gobiopterus brachypterus*, and *Tor tambroides*. The catchment area of the Ranggeh River began to change a lot due to agriculture and human settlements. The presence of nutrient enrichment and toxic pollutants from agricultural and residential waste can threaten the life of river biota, including benthic macroinvertebrates. Pesticide application and agricultural fertilizers can contribute 43% of chemical oxygen demand, 67% phosphorous, and 57% nitrogen to river bodies (Watts 2010). Poor water quality can impact decreasing biodiversity, changing functional feeding, and leaving species that are classified as tolerant (Duan, Wang & Xu 2011). Water quality studies of the Ranggeh River at the community structure level have been carried out previously (Sudarso et al. 2021). However, its impact on FFG has not been evaluated, so this has prompted this research. This study aimed to analyze and observe changes in water quality by anthropogenic activities and their impact on functional feeding groups of benthic macroinvertebrate organisms in Ranggeh River.

Materials and Methods

STUDY AREAS

Samples were taken from February to August 2019 on the Ranggeh River section. Four observation stations have been established based on the types of anthropogenic activities and pollutant loads that enter the Ranggeh River. The characteristics of each sampling location was determined directly from field observations. The sampling locations and their explanations can be seen in Table 1 and Figure 1.

SAMPLING, IDENTIFICATION, AND DETERMINATION OF MACROINVERTEBRATE BENTHIC FFG

Benthic macroinvertebrates were collected in the river using a Hess sampler (30 cm diameter) with a 0.5 mm sieve pore. All samples were carried out in the riffle section because they generally have diversity and are sensitive to disturbances compared to pools (De Pauw, Gabriels & Goethals 2006; Klemm et al. 1990). Samples were composited in each sampling location in the left side, right side and in the middle of the river. Sample replication were conducted three times. The collected organisms were rinsed with water and preserved with 70 % alcohol (Barbour et al. 1996). The sample is put in a ziplock plastic bag and given a description/location label. Sorting was performed under an Olympus SZ 61 stereo microscope at a magnification of up to 80 times. Identification of macroinvertebrates was attempted to the genus level using identification keys from Merritt and Curnmins (2019), Thorp and Covich (1991) and Yule and Sen (2004). The FFG classification of each benthic macroinvertebrate organism found was based on Barbour et al. (1999) and Merritt and Curnmins (2019).

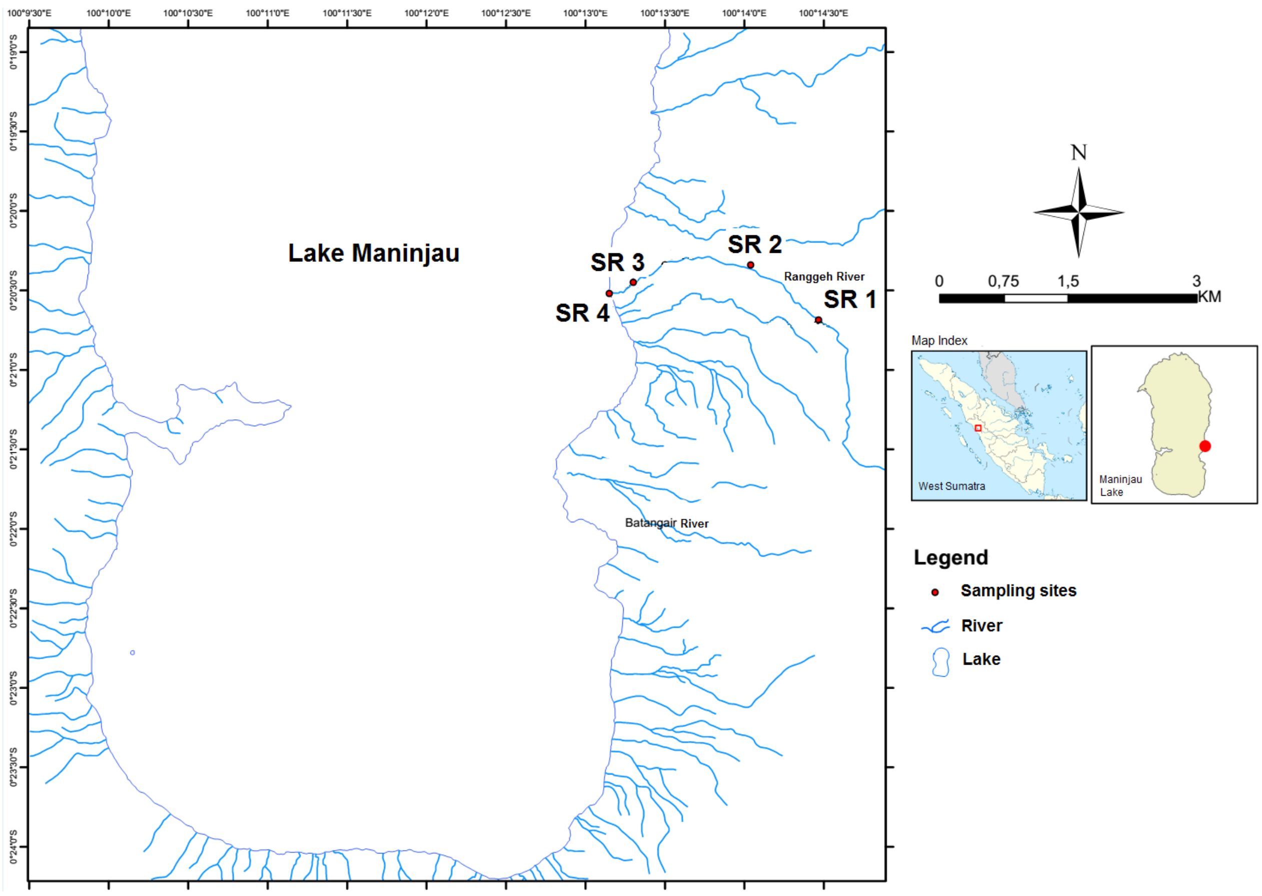


FIGURE 1. Location map of benthic macroinvertebrates sampling in Ranggeh River

WATER QUALITY MEASUREMENT

Water quality parameters measurement in the Ranggeh River was carried out directly or indirectly (in the laboratory). Parameters measured directly in the field include dissolved oxygen (DO), pH, temperature, conductivity, % embeddedness, and turbidity were measured using water quality checker Horiba U-50. The percentage of the number of stones embedded in the riverbed (% embeddedness) was carried out qualitatively at each observation station (Hamid & Rawi 2011). Water quality parameters which were analysed in the laboratory included: total nitrogen (TN) and total phosphorous (TP). Because the width of the Ranggeh River is relatively small (1-1.5 m), the collection and measurement of water quality were carried out in the middle of the river. Water samples for TN and TP analysis were 500 mL using HDPE (high-density polyethylene) plastic bottles. The analysis of TP and TN were carried out in the Research Center for Limnology-LIPI using a Shimadzu 1800 UV-Vis spectrophotometer.

TABLE 1. Descriptions of the habitat in each sampling location

River characteristics	Stations			
	SR1	SR2	SR3	SR4
Coordinate point	S: 0^{0}20'34,0" E: 100^{0}14'19"	S: 0^{0}20'33,1" E: 100^{0}14'15"	S; 0^{0}20'50,1" E:100^{0}13"24,1"	S: 0^{0}20"51,3" E: 100^{0}13"17,1"
Altitude (m above sea level/ asl)	810	625	450	449
River Depth (cm)	± 50	± 30 cm	±20 cm	±20 cm
River width (cm)	± 80 cm	± 80 cm	± 50 cm	± 50 cm
Discharge	0.18 m^3/second	0.04 m^3 / second	0.03 m^3/second	0.04 m^3/second
Condition on right side	rice fields	rice fields	rice fields	rice fields
Condition on left side	forest	rice fields	rice fields	rice fields
Riverbed Substrate	Large and small rocks	Large and small rocks	fine sand	small rocky, fine sand
Water clarity	Clear	Cloudy	Cloudy	Cloudy

TN measurement was measured using the alkaline potassium persulfate digestion-UV spectrophotometric method, while the TP was carried out using the ammonium molybdate spectrophotometric method (APHA 2005). The potential risk of disturbance caused by the measured water quality parameters is compared to the guidelines of the Government of the Republic of Indonesia No. 82 of 2001 for water quality class II (fishery).

DATA ANALYSIS

The differences of functional type abundance data and environmental quality parameters among observation stations were tested using one-way analysis of variance (ANOVA). The Liliefor test for normality was applied, prior to the ANOVA. Kruskall-Wallis non-parametric analysis was applied to data that were not normally distributed. A simple correlation analysis (pearson product moment) was carried out between the abundance data of each FFG and water quality parameters. The quality status of water pollution by organic matter is carried out using The Minimum Water Quality Index (WQImin) as described in Simões et al. (2008). All statistical analysis were performed using Statistica software version 11 (Statsoft Inc.).

The contribution of each water quality variable in each type of FFG was carried out using a multivariate canonical correspondence analysis (CCA). CCA analysis was performed using MVSP version 3.22 software (Covach Ltd).

RESULTS

The results of the normality test on functional feeding groups and environmental variables using the Liliefor test showed that several FFG and environmental parameters were not normally distributed ($p < 0.01$), including: predators, collector filterers, scrapers, collector gatherers, omnivores, turbidity, current velocity, and TN. Therefore, Kruskal-Wallis test was used for testing the differences among those parameters.

The results of monitoring the water quality of the Ranggeh River from February to August 2019 are briefly shown in Table 2. The table shows the influence of agriculture and human settlements on the improvement of several water quality parameters. Several water quality parameters observed showed significant differences ($p < 0.05$) between observation stations: pH, DO, temperature, turbidity, current speed, and % embeddedness. However, other parameters such as conductivity, TN, and TP were not significantly different ($p > 0.05$) between observation stations. The water quality parameters of the Ranggeh River are compared with the water quality standards of the Republic of Indonesia to support fisheries, so only the turbidity parameter has exceeded (> 5 NTU). Other parameters (pH, DO, conductivity, temperature, current speed, TN, TP) are still within the allowable range to support fisheries in general.

TABLE 2. Ranggeh River water quality (mean ± SD) and significance level ($p = 0.05$). The guidelines are based on the Republic of Indonesia's Government Regulation for water quality class II (fisheries). Description: Dev = deviation

Parameters	Sampling Sites				Guideline	probability
	SR1	SR2	SR3	SR4		
pH	7.8±0.57	7.8±0.6	7.08±0.2	7.3±0.3	6-9	p = 0.0319
DO (mg/l)	8.2±0.6	7.9±0.5	6.2±0.94	6.2±0.56	6	p = 0.0002
Conductivity (mS/cm)	0.098±0.03	0.101±0.03	0.15±0.02	0.15±0.05	-	p = 0.09
Turbidity (NTU)	7,04±9,44	51,03±23,9	43,43±89,1	45,33±90	5	p = 0.02
Temperature (^{0}C)	21.5±0.34	23.6±1.6	27,26±0,8	27, 69±1,1	Dev.3	p = 0.00001
Current speed (m/det)	2,72±1,38	0,84±0,49	0,58±0,41	0,68±0,45	-	p = 0.03
TN (mg/l)	0.54±0.4	0.68±0.3	0.54±0.16	0.6±0.37	10	p = 1
TP (mg/l)	0.05±0.05	0.07±0.05	0.06±0.02	0.06±0.03	0.2	p = 0.939
% Embeddedness	20±1,3	31 ±1,3	46±9,1	52±9,4	-	p = 0.00001

The status of organic pollution that occurs in the Ranggeh River using WQI_{min} is listed in Table 3. The table shows that the SR1 station, which is still minimally disturbed by agricultural activities, has criteria still classified as very good (WQI_{min} average value is 96.7). Station SR2 has experienced interference in the moderate category with an average WQI_{min} value of 67.8. While Stations SR3 and SR4 are in the status of relatively good water quality criteria (mean WQI_{min} 76.7 and 70.6).

TABLE 3. Status of organic pollution at each observation station

Stations	Value of WQI_{min} (minimum-maximum)	Mean ±SD	Criteria
SR1	83-100	96.7±6.7	Very good
SR2	57-77	67.8±8.3	Moderate
SR3	50-90	76.7±15	Good
SR4	63-80	70.6±10.2	Good

Observations of the abundance of benthic macroinvertebrate FFG in the Ranggeh River from February to August 2019 are presented in percentage average (Figure 2). The composition and type of FFG of each benthic macroinvertebrate organism in the Ranggeh River are listed in Appendix 1. The variation in the relative abundance of FFG at each observation station is shown in the form of a Whisker and Plot graph (Figure 3). Figure 2 shows that the upper part of the Ranggeh River (SR1) has a relatively higher average percentage of predator abundance compared to other stations. The results of the ANOVA test on predatory FFGs showed a significant difference between SR1 and other stations (F = 9.365, p = 0.000451). However, for SR2 to SR4, there was no significant difference (Figure 3). The collector-filter in SR2 shows a higher average percentage abundance value than other stations. However, the ANOVA test results from the collector–filterer did not show a significant difference between the observation stations (F = 0.853 and p = 0.48). The shredder in SR1 shows a higher average percentage of abundance than other stations. The results of the ANOVA test of the relative abundance of shredder at the observation station showed a significant difference between SR1 and other stations (F=7.14, p = 0.0019). However, for SR2 with other stations, it was not significantly different ($p > 0.05$). The collector-gatherer in Ranggeh River shows that SR3 and SR4 have a higher mean percentage of abundance than SR1 and SR2 stations. The results of the ANOVA test on the relative abundance of FFG Collector-gatherers showed a significant difference between stations SR1, SR2, and SR3, SR4 (F = 4.44, p = 0.015). The mean percentage of scraper abundance in the upstream part of the river (SR1) was relatively higher and significantly different from other stations (F = 3.24, p = 0.043). The results of observations of the average percentage abundance of omnivores at each observation station were relatively minimal, and the relative abundance was not significantly different between observation stations (F = 1, p = 0.413).

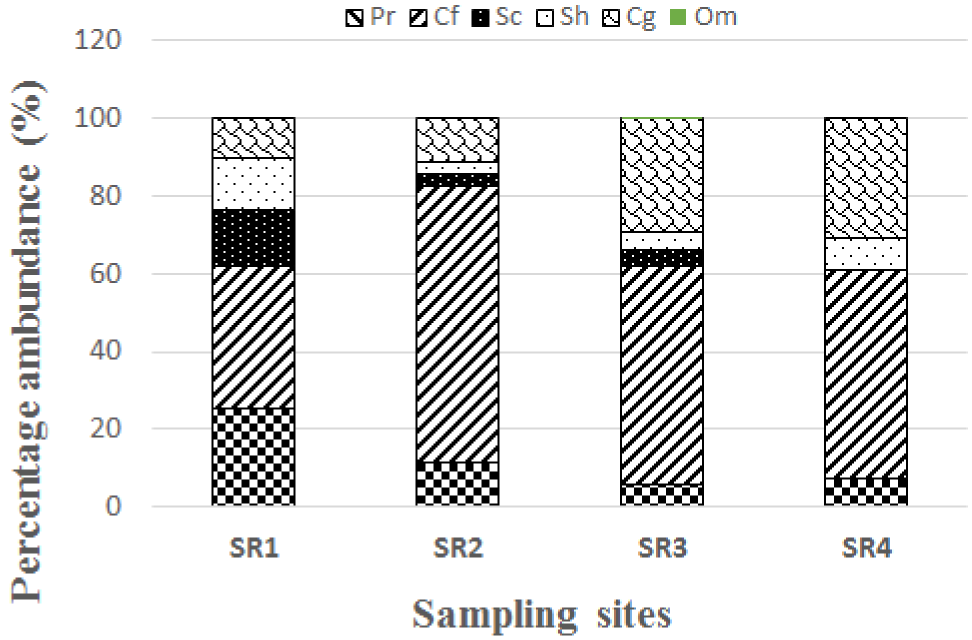
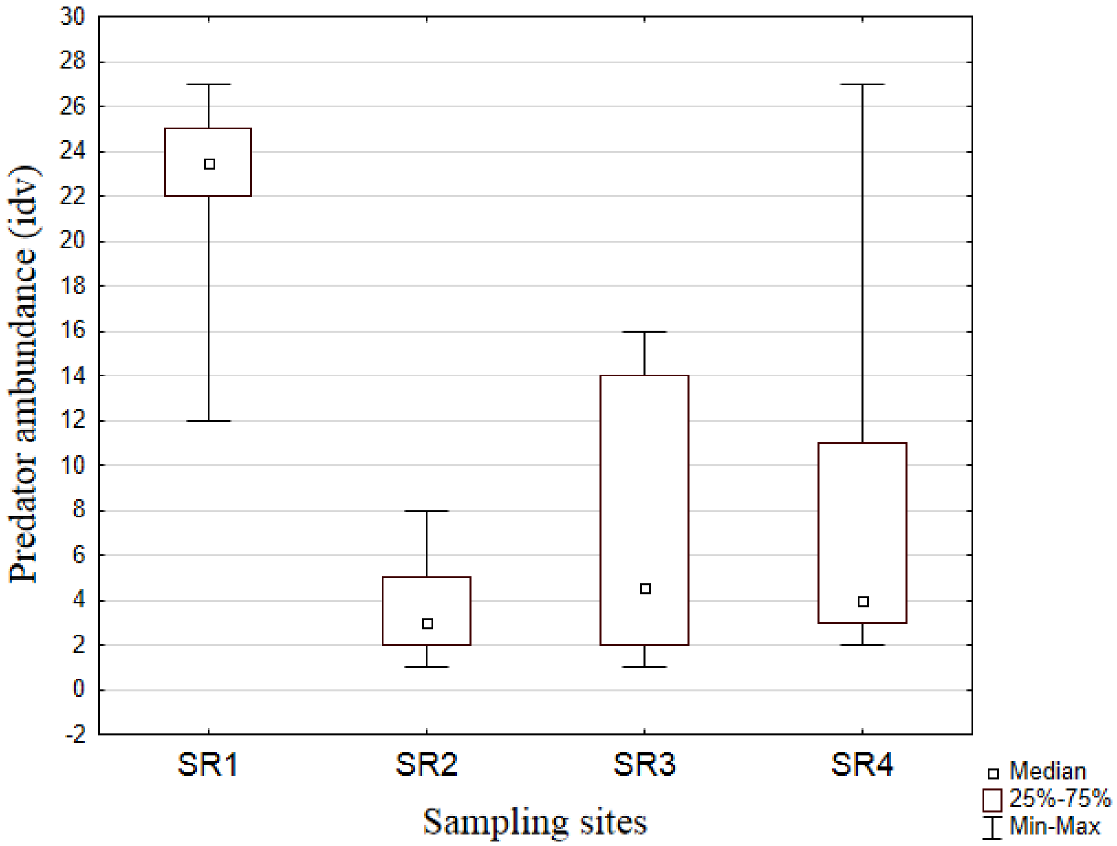
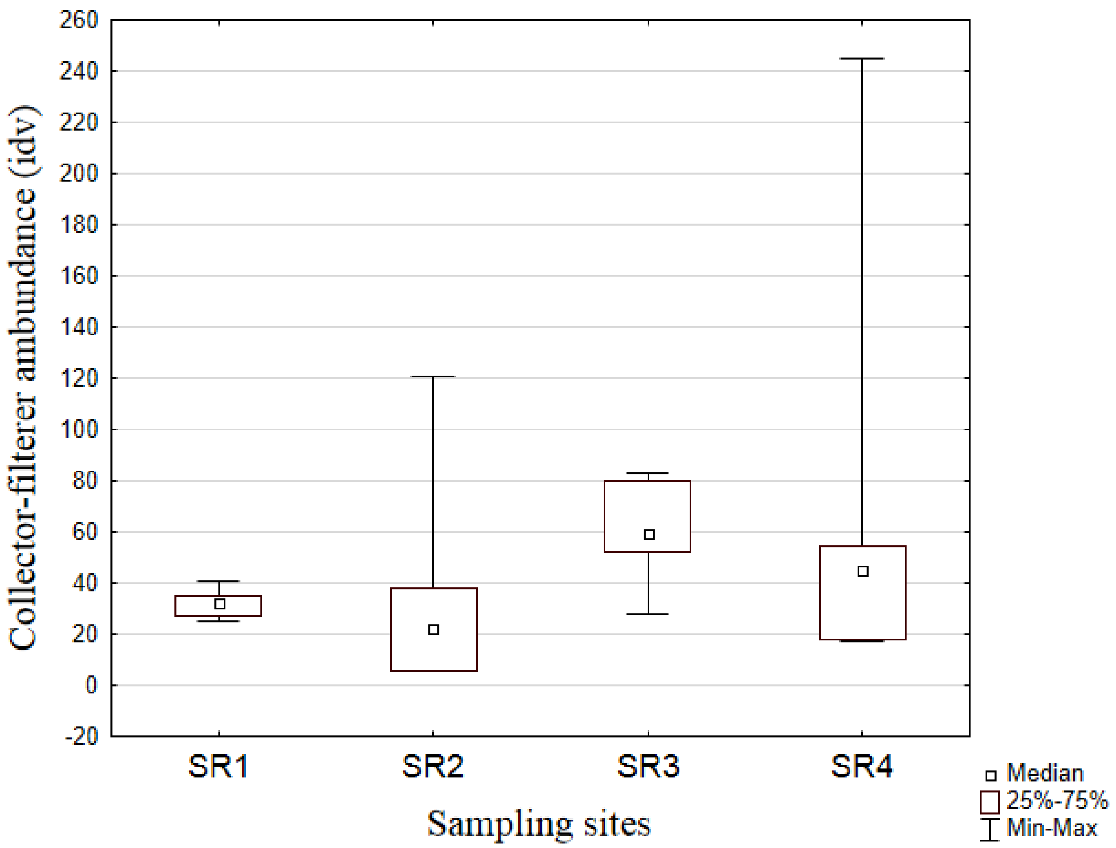
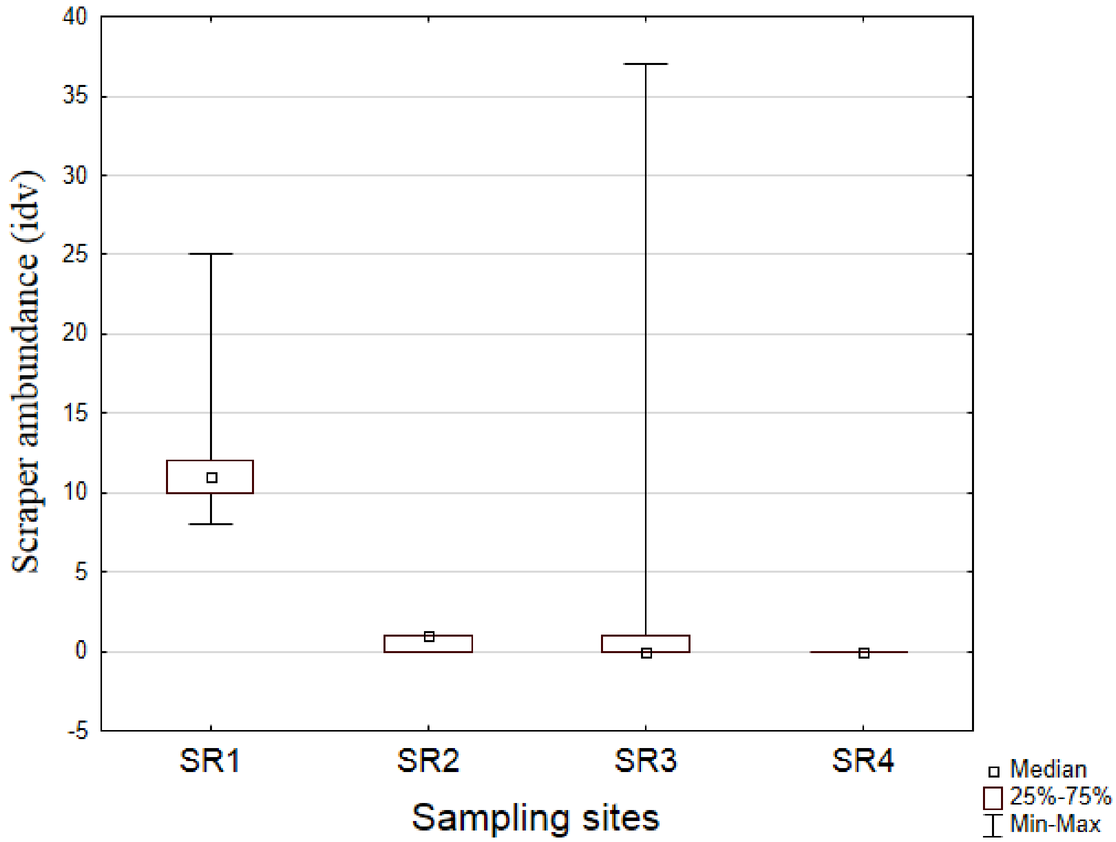
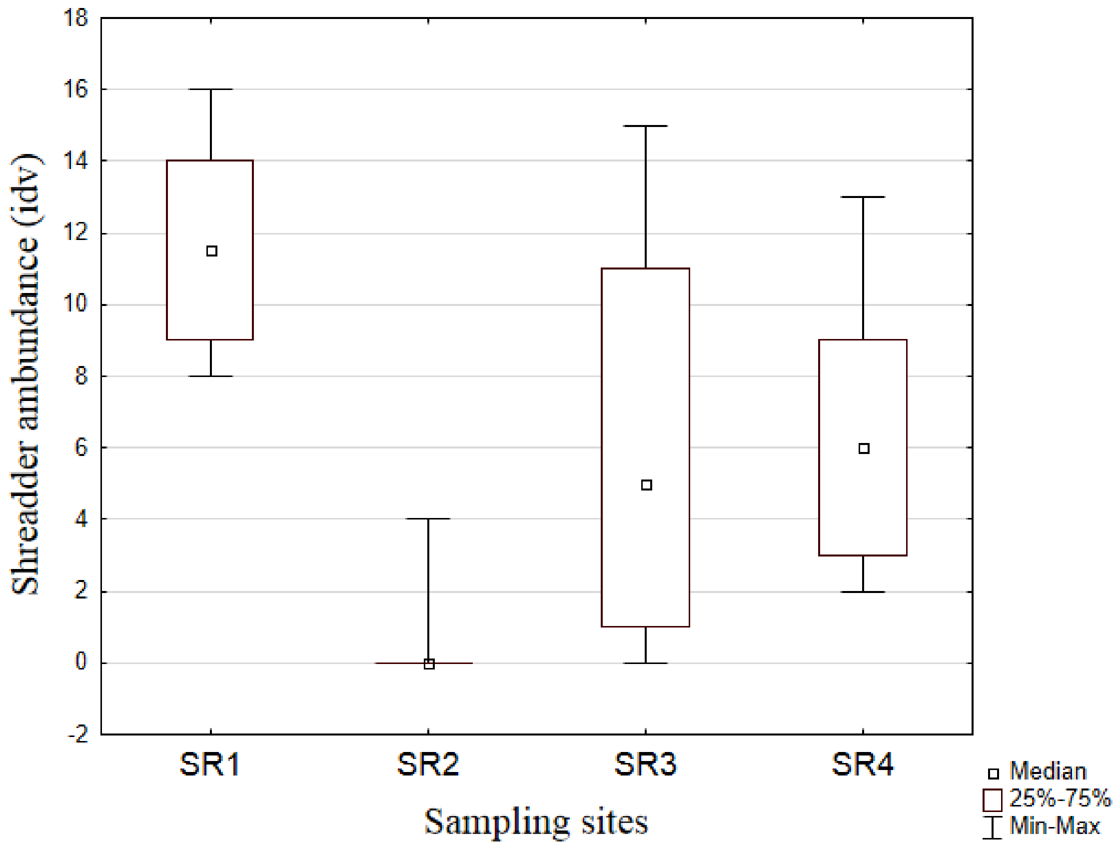


FIGURE 2. Average percentage of FFG benthic macroinvertebrate abundance in Ranggeh River (explanation: Pr = predators, Cf = collector-filterers, Sc = Scrapers, Sh = Shreadders, Cg = Collector-gatherers, Om = Omnivores)


Predator ambundance (idv)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
-2
SR1
SR2
SR3
SR4
Sampling sites
Median
25%-75%
Min-Max


Collector-filterer ambundance (idv)
260
240
220
200
180
160
140
120
100
80
60
40
20
0
-20
SR1
SR2
SR3
SR4
Sampling sites
Median
25%-75%
Min-Max


Scraper ambundance (idv)
40
35
30
25
20
15
10
5
0
-5
SR1
SR2
SR3
SR4
Sampling sites
Median
25%-75%
Min-Max


Shreadder ambundance (idv)
18
16
14
12
10
8
6
4
2
0
-2
SR1
SR2
SR3
SR4
Sampling sites
Median
25%-75%
Min-Max

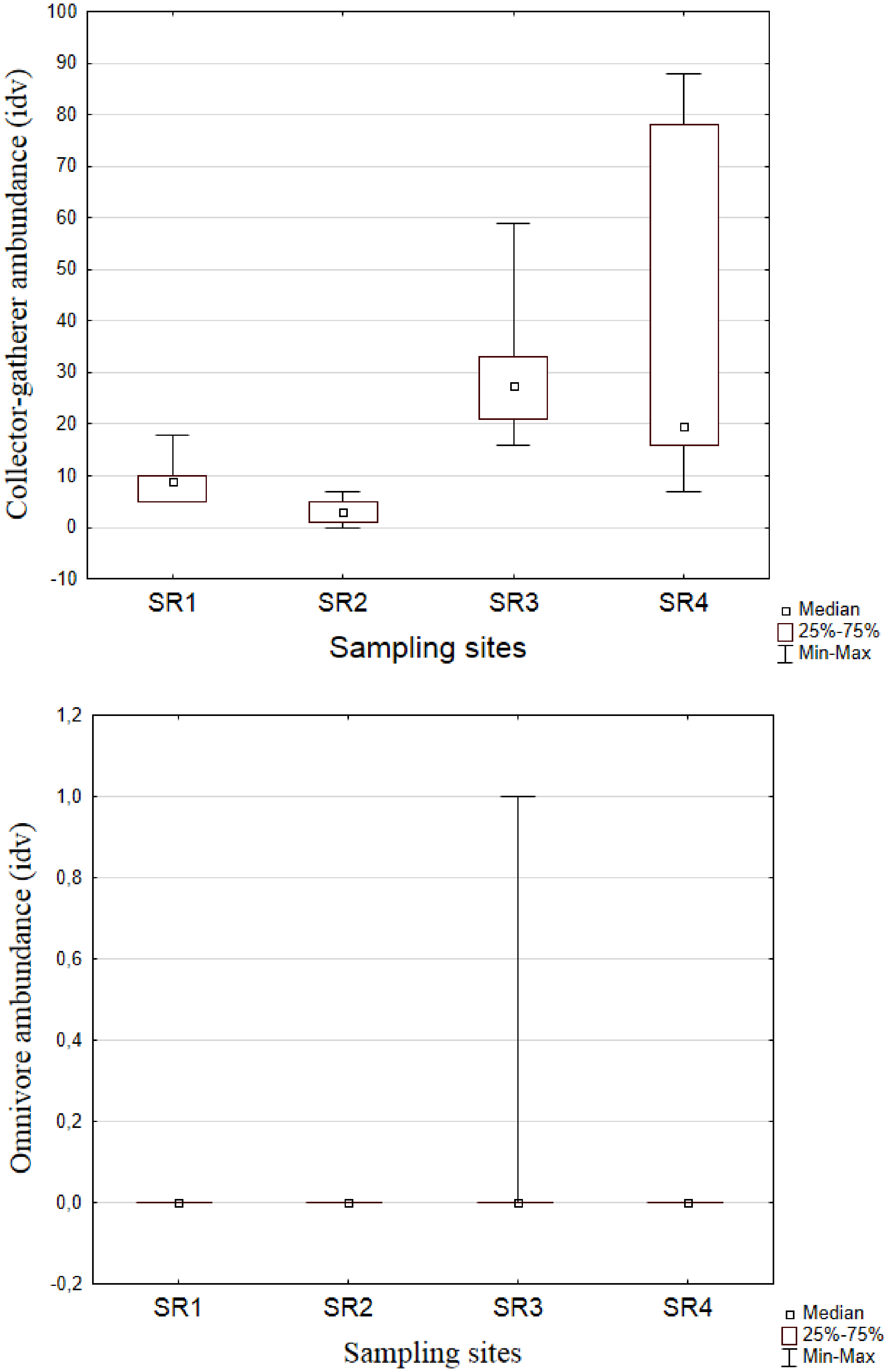


FIGURE 3. Whisker graph and plot of the abundance of each FFG at each observation station (explanation: Pr = predators, Cf = collector-filterers, Sc = Scrapers, Sh = Shreadders, Cg = Collector-gatherers, Om = Omnivores)

The multivariate analysis using the CCA ordination is shown in Table 4 and Figure 4. In the table, the results on the two main axes are as follows: cumulative constrained percentage values on axes one and two are 75.8% and 92.1%, with species-environment correlation values of 0.91 and 0.6. Based on the cumulative constrained percentage value to the two axes, it shows the adequacy of the information obtained by 92.1% of the linear combination between environmental variables and species data. This condition is feasible to describe almost all interactions between environmental variables and species data in the ordination space. Triplot graph between FFG, environmental variables, and observation stations show in Figure 4. Figure 4 shows that there are three groupings, namely: SR1 (group1), SR2 (group2), and SR3 and SR4 (Group 3). The dominant predators, scrapers, and shredders groups in SR1 (right side of the graph) tend to be characterized by environmental variables: relatively high current velocity and DO relatively low temperature and % embeddedness.

On the other hand, the dominant collector-filterers and collector-gatherers in SR3 and SR4 are characterized by relatively high temperature and % embeddedness, lower current velocity, and DO. The omnivorous approach from the center of the ordination of the study did not indicate a dominant variable in regulating its abundance. The value of the water quality environmental variable is shown in Table 2.

TABLE 4. CCA ordination results from FFG benthic macroinvertebrates in the Ranggeh River

	Axis 1	Axis 2
Eigenvalues	0.182	0.039
Percentage	46.503	10.026
Cumulative percentage	46.503	56.529
Cumulative constrained percentage	75.772	92.108
Species-environmental correlations	0.91	0.6

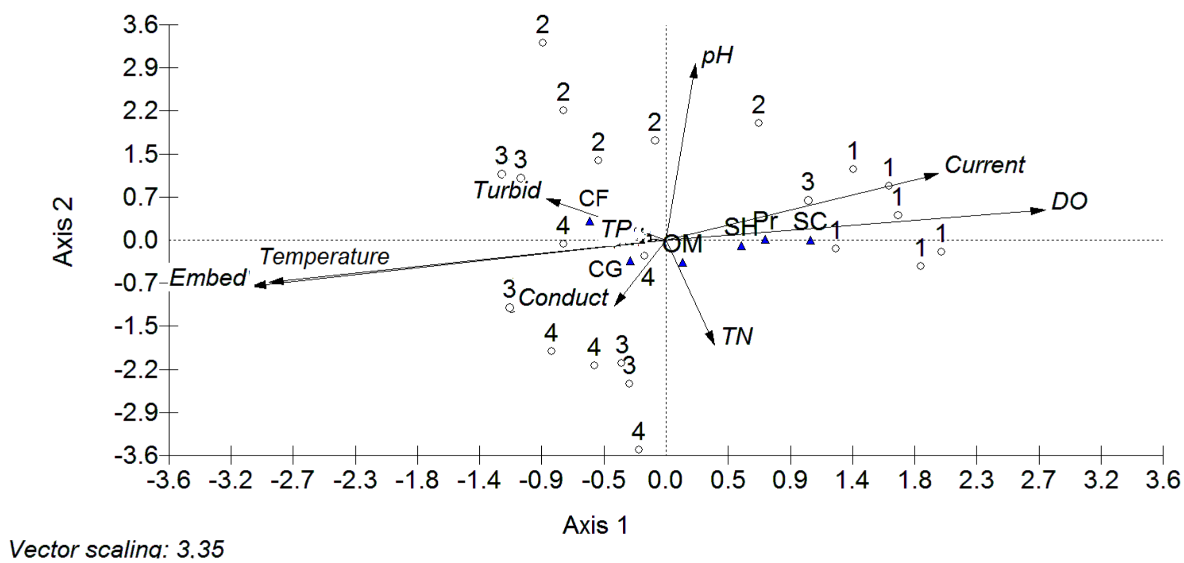


FIGURE 4. Triplot graph of CCA ordination results on environmental variables, observation stations, and FFG benthic macroinvertebrate in Ranggeh River (explanation: embed = % embeddedness, turbid = turbidity, conduct = conductivity)

The correlation magnitude between the abundance of each FFG and the water quality variable is shown in Table 5. The table shows a significant positive correlation ($p<0.05$) between predatory and the DO and flows velocity variables and a negative correlation with the temperature, turbidity variables, % embeddedness and WQI_{min}. The collector-filterers and collector-gatherers were significantly positively correlated ($p<0.05$) with temperature and % embeddedness. The scrapers has a significant negative correlation with % embeddedness variable. Shredders showed a significant positive correlation with WQI_{min}. Omnivore did not show any correlation with the variables used in this study.

TABLE 5. Pearson product-moment (r) correlation value between environmental variables and functional feeding groups. The numbers in bold are significant at the p = 0.05 level (explanation: Pr = predators, Cf = collector-filterers, Sc = Scrapers, Sh = Shredders, Cg = Collector-gatherers, Om = Omnivores)

No	Parameter	Functional feeding groups					
		Pr	Cf	Sc	Sh	Cg	Om
1	pH	0.003	-0.002	-0.087	-0.15	-0.39	-0.30
2	DO	0.5	-0.35	0.31	0.27	-0.39	-0.11
3	Conductivity	-0.21	-0.01	0.05	-0.08	0.13	0.29
4	Turbidity	-0.5	-0.05	-0.2	-0.28	-0.13	-0.07
5	Temperature	-0.5	0.5	-0.28	-0.26	0.6	0.22
6	Current speed	0.53	-0.118	0.21	0.36	-0.26	-0.13
7	Total nitrogen	0.16	-0.104	0.04	0.001	0.15	0.14
8	Total phosphorous	0.03	0.15	0.06	0.142	0.129	0.214
9	% Embededdnes	-0.52	0.5	-0.5	-0.28	0.5	-0.03
10	WQI_{min}	-0.59	-0.12	0.29	-0.52	-0.05	-0.11

DISCUSSION

This study showed that when the Ranggeh River ecosystem still receives minimal disturbance from agricultural activities (SR1), FFG predators, shredders, and scrapers dominate the waters. However, when agricultural activities and human settlements became more massive in SR2 to SR4, the dominant FFG were collectors (filterers and gatherers). The riparian vegetation in SR1 is still forest on the left, and the right side is rice fields. Fu et al. (2015) mention that rivers in forest areas generally have characteristics: low temperature and river order, high pH, elevation, DO, and rough substrate compared to regions affected by land-use practices (agriculture, urbanization). Taxa richness and densities of shredders and predators are usually higher in forest areas than urban areas. Leaf fall is the primary energy source of allochthonous organic matter in rivers (Benfield 1997; Vimos-Lojano et al. 2020). Graca et al. (2015) stated that leaf litter is easily leached, colonized, and decomposed by microbes and is the main food of the shredders group. Another environmental factor that supports the dominance of the three FFG groups above is the low turbidity value in SR1. Low turbidity values can optimize predatory FFG in searching and getting prey. During the rainy season, the turbidity value at station SR1 can reach 26.3 NTU. However, most of them are still around ± 3 NTU (mean 7 NTU). Sunlight can encourage the growth of epilithic algae, which serves as a food source for scrapers. Bhawsar, Bhat and Vyas (2015) showed the dominance of scrapers in the Barna

River in the forest environment was up to 58%. Scrapers abundance is usually related to riffle habitat conditions and the abundance of epilithic algae in rivers (Vyas & Bhawsar 2013). The relatively good water conditions are ideal for predators, shredder, and scraper functional feeding groups (Shearer & Young 2011).

The monitoring results of water quality on the Ranggeh River show that the impact of agriculture and settlements is more inclined towards sedimentation than organic enrichment (TN and TP). The turbidity values in SR2 to SR4 tend to be high, which can interfere with the life of benthic macroinvertebrate organisms in general. Turbidity values beyond 23 NTU could reduce taxa richness and density of most benthic macroinvertebrate organisms (Quinn et al. 1992). The further downstream, the value of turbidity and % embeddedness tends to increase. Physically suspended fine particles can trigger the formation of sediments and change the bottom habitat of the waters (Kemp et al. 2011). Hamid and Rawi (2011) stated that the taxa Ephemeroptera, Plecoptera, and Trichoptera tend to be low when the % embeddedness in rivers reaches 50-75%. Shieh and Yang (2000) stated that sedimentation could reduce the density of FFG scrapers, shredders, and predators. The sedimentation effects on benthic macroinvertebrates by reduction of dissolved oxygen supply which is causing hypoxia, inhibiting the growth of epilithic algae, hindering prey search by predators, inhibiting egg and embryo development, reducing the larval length and weight, and being able to change morphological adaptations (Kemp et al. 2011).

The collector–filterer and collector-gatherer FFG groups dominate in SR2 to SR4 downstream. These results are also similar to several studies conducted by several previous researchers in China (Fu et al. 2015; Hu et al. 2005; Jiang et al. 2011; Qu et al. 2007) and the Austral rivers in South Africa (Mangadze et al. 2017) which shows an increase in collector-gatherer downstream. The dominance of collector–filterer and collector–gatherer usually reflects the enrichment of organic matter in the waters (Rosenberg & Resh 1993). The collector-gatherer population will increase when the input of allochthonous organic matter is high (Bispo et al. 2006; Dobson et al. 2003; Mangadze et al. 2017). Compin and Céréghino (2007) show that collector-gatherers have a higher percentage in the Adour-Garonne urban-landscape stream area. Therefore, the density of FFG collectors is the best candidate for assessing the effect of land use on Patagonian streams (Miserendino & Masi 2010). Fu et al. (2015) stated that collector-gatherers would be abundant with increasing TP gradient downstream of the urban site due to input from sewers and fertilizers. FFG collector-gatherers are generally relatively resistant to organic pollution and can adapt physiologically and physically in low dissolved oxygen conditions (Mangadze et al. 2017). The collector-filterers FFG that dominates in SR2 to SR4 is one form of morphological adaptation of increasing turbidity in the waters. As an example of a collector-filterer: Trichoptera Hydropsychid larvae filter food particles through a net made in their nest. The Diptera Simulid larvae group can filter suspended food through a comb in its mouth (Kemp et al. 2011).

Another FFG most affected by sedimentation in the Ranggeh River (SR2 to SR4) is the scrapers. This is caused by the interference of the scrapers to reach or get food (epilithic algae) because of fine sediment particles covering it. FFG scraper is highly dependent on autochthonous production in waters, such as plant tissue and epilithic algae that grow on submerged substrates (Cummins & Klug 1979; Rosenberg & Resh 1993). Fine particles of sediment can cover and disturb the respiratory organs (gills) in benthic macroinvertebrate organisms (Kemp et al. 2011), such as the scraper-type nymph Ephemeroptera. The high % Embeddedness at stations SR3 and SR4 can cover the interstitial space, resulting in low dissolved oxygen.

The results of the Pearson product-moment correlation analysis between FFG and WQI_{min} showed that predators and shredders were relatively sensitive in detecting the effect of sedimentation compared to other FFGs. From the graphs of the whisker and FFG plots, predators are somewhat superior to shredders in separating areas with minimal disturbance (SR1) and sites that have experienced disturbance (SR2 to SR4). SR2 is the area most affected by agricultural activities so that some water quality parameters tend to be higher (TN, TP, turbidity) than SR3 and SR4. The water quality in SR3 and SR4 is relatively better than SR2 due to input from springs and river restoration activities in August to add basic substrate (gravel). This condition can affect the abundance of predators and shredder FFG, increasing in SR3 and SR4. Fu et al. (2015), who researched the Dongjian River, showed that shredders and predators are more suitable as indicators to assess the effect of agricultural practices and urbanization than other FFGs. The shredders and scrapers are relatively sensitive reflecting disturbances that occur in the aquatic environment, while collector gatherers and filterers are more tolerant (Barbour et al. 1996). FFG predators and shredders usually live in clean water conditions with minimal influence from land use (Miserendino & Pizzolon 2003; Weliange 2017). However, shredder groups are sometimes relatively rare in tropical rivers in Africa, Asia, Neotropic, and south-temperate New Zealand (Dobson et al. 2002; Dudgeon & Wu 1999; Moyo & Richoux 2017; Weliange et al. 2017).

CONCLUSIONS

From this study, it can be concluded that anthropogenic activities that occur in the Ranggeh River can result in changes in water quality due to sedimentation and organic matter enrichment. The impact of sedimentation on benthic macroinvertebrate FFG is more dominant than organic matter enrichment in the waters. Predatory FFGs, shredders, and scrapers are most affected by agricultural and human settlement anthropogenic activities. FFG collectors will increase when agricultural activities and human settlements become more massive around the Ranggeh River.

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REFERENCES

APHA. 2005. *Standard Methods for the Examination of Water and Waste Water*. New York: American Public Health Association.

Barbour, M.T., Gerritsen, J., Snyder, B.D. & Stribling, J.B. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish*. 2nd ed. US-EPA, Office of Water Washington. DC.

Barbour, M.T., Gerritsen, J., Griffith, G.E., Frydenborg, R., McCarron, E., White, J.S. & Bastian, M.L. 1996. A framework for biological criteria for Florida streams using benthic macroinvertebrates. *Journal of the North American Benthological Society* 15: 185-211.

Benfield, E.F. 1997. Comparison of litterfall input to streams. *Journal of the North American Benthological Society* 16(1). https://doi.org/10.2307/1468242

Bhawsar, A., Bhat, M.A. & Vyas, V. 2015. Distribution and composition of macroinvertebrates functional feeding groups with reference to catchment area in barna sub-basin of Narmada River Basin. *International Journal of Scientific Research in Environmental Sciences* 3(11): 385-393.

Bispo, P.C., Oliveira, L.G., Bini, L.M. & Sausa, K.G. 2006. Ephemeroptera, Plecoptera and Trichoptera assemblages from riffles in mountain streams of central Brazil: Environmental factors influencing the distribution and abundance of immatures. *Brazilian Journal of Biology* 66(2B): 611-622.

Compin, A. & Céréeghino, R. 2007. Spatial patterns of macroinvertebrate functional feeding groups in streams in relation to physical variables and land-cover in Southwestern France. *Landscape Ecology* 22: 1215-1225.

Cummins, K.W., Merritt, R.W. & Andrade, P.C.N. 2005. The use of invertebrate functional groups to characterize ecosystem attributes in selected streams and rivers in south Brazil. *Studies on Neotropical Fauna and Environment* 40(1): 69-89.

Cummins, K.W. & Klug, M.J. 1979. Feeding ecology of stream invertebrates. *Annual Review of Ecology and Systematics* 10: 147-172.

De Pauw, N.W., Gabriels, P. & Goethals, L.M. 2006. River monitoring and assessment methods based on macroinvertebrates. *Biological Monitoring of Rivers: Applications and Perspectives*, edited by G. Ziglio, M. Siligardi, and G. Flaim. New York: John Wiley & Sons.

Dobson, M., Magana, A., Mathooko, J.M. & Ndegwa, F.K. 2002. Detritivores in Kenyan highland streams: More evidence for the paucity of shredders in the tropics? *Freshwater Biology* 47: 909-919. https://doi.org/10.1046/j.13652427.2002.-00818.x

Dobson, M., Mathooko, J.M., Ndegwa, F.K. & M'Erimba, C. 2003. Leaf litter processing rates in a Kenyan highland stream, the Njoro River. *Hydrobiologia* 519: 207-210. https://doi.org/10.1023/B:HYDR.0000026592.50734.ea

Duan, X.H., Wang, Z.Y. & Xu, M.Z. 2011. Effects of fluvial processes and human activities on stream macroinvertebrates. *International Journal of Sediment Research* 26: 416-430.

Dudgeon, D. & Wu, K.Y. 1999. Leaf litter in a tropical stream: Food or substrate for macroinvertebrates? *Archiv für Hydrobiologie* 146: 65-82. https://doi.org/10.1127/ archiv-hydrobiol/146/1999/65.

Ferreira, V., Encalada, A.C. & Graça, M.A.S. 2012. Effects of litter diversity on decomposition and biological colonization of submerged litter in temperate and tropical streams. *Freshwater Science* 32: 945-962. doi:10.1899/11-062.1

Fu et al. 2015

Graça, M.A.S., Ferreira, V., Canhoto, C., Encalada, A.C., Guerrero-Bolaño, F., Wantzen, K.M. & Boyero, L. 2015. A conceptual model of litter breakdown in low order streams. *International Review of Hydrobiology* 100: 1-12. https://doi.org/10.1002/iroh.201401757

Hamid, S.A. & Rawi, C.S. 2011. Influence of substrate embeddedness and canopy cover on the distribution of Ephemeroptera, Plecoptera and Trichoptera (EPT) in tropical rivers. *Aquatic Insects: International Journal of Freshwater Entomology* 33(4): 281-292.

Hu, B.J., Yang, L.F., Wang, B.X. & Shan, L.N. 2005. Functional feeding groups of macro invertebrates in 1-6 order tributaries of the Changjiang River. *Chinese Journal of Applied & Environmental Biology* 11: 463-466.

Jiang, X.M., Xiong, J., Xie, Z.C. & Chen, Y.F. 2011. Longitudinal patterns of macroinvertebrate functional feeding groups in a Chinese river system: A test for river continuum concept (RCC). *Quaternary International* 244: 289-295.

Kemp, P., Sear, D., Collins, A.N., Aden, P. & Jones, I. 2011. The impacts of fine sediment on riverine fish. *Hydrological Processes* 25: 1800-1821.

Klemm, D.J., Lewis, P.A., Fulk, F. & Lazorchak, J.M. 1990. *Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters*. Washington: U.S. Environmental Protection Agency.

Mangadze, T., Wasserman R.J., Froneman, P. W., & Dalu T. 2017, Macroinvertebrate functional feeding group alterations in response to habitat degradation of headwater Austral streams, *Science of the Total Environment* 695:1-9

Merritt, R.W., Cummins, K.W., Berg, M.A.B., Novak, J.A., Higgins, M.J., Wessell, K.E.J. & Lessard, J.L. 2002. Development and application of a macroinvertebrate functional-group approach in the bioassessment of remnant river oxbows insouthwest Florida. *Journal of the North American Benthological Society* 21(2): 290-310.

Merritt, R.W. & Cummins, K.W. 2019. *An Introduction of the Aquatic Insects of North America*. 5th ed. Dubuque. Iowa: Kendall Hunt Publishing Company. p. 1498.

Menezes, S., Baird, D.J. & Soares, A.M. 2010. Beyond taxonomy: A review of macro invertebrate trait-based community descriptors as tools for freshwater biomonitoring. *Journal of Applied Ecology* 47: 711-719.

Miserendino, M.L. & Masi, C.I. 2010. The effects of land use on environmental features and functional organization of macroinvertebrate communities in Patagonian low order streams. *Ecological Indicators* 10: 311-319.

Miserendino, M.L. & Pizzolon, L.A. 2003. Distribution of macroinvertebrate assemblages in the Azual-Quemquemtreu river basin, Patagonia, Argentina. *New Zealand Journal of Marine and Freshwater Research* 37: 525-539. https://doi.org/10.1080/ 00288330.2003.9517187

Moyo, S. & Richoux, N.B. 2017. Macroinvertebrate functional organisation along the longitudinal gradient of an austral temperate river. *African Zoology* 52(3): 125-136.

Nautiyal, P. & Mishra, A. 2013. Variations in benthic macroinvertebratefauna as indicator of land use in the Ken River, central India. *Journal of Threatened Taxa* 5: 4096-4105.

Qu, X.D., Cai, Q.H., Xie, Z.C., Tang, T., Cao, M. & Li, D.F. 2007. Research of functional of feeding groups of macro invertebrate in the stony habitat of the Xiangxi River system. *Resources and Environment in the Yangtze Basin* 16: 738-743.

Quinn, J.M., Davies-Colley, R.J., Hickey, C.W., Vickers, M.L. & Ryan, P.A. 1992. Effects of clay discharges on streams. 2. Benthic invertebrates. *Hydrobiologia* 248: 235-247.

Ramirez, A. & Gutierrez-Fonseca, P.E. 2014. Functional feeding groups of aquatic insect families in Latin America: A critical analysis and review of existing literature. *Revista de Biología Tropical* 62(Suppl. 2): 155-167.

Rosenberg, D. & Resh, V.H. 1993. *Freshwater Biomonitoring and Benthic Macroinvertebrates*. New York: Chapman and Hall.

Shearer, K.A. & Young, R.G. 2011. Influences of geology and land use on macroinvertebrate communities across the Motueka River catchment, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 45(3): 437-454. DOI: 10.1080/ 00288330.2011.587823

Shieh, S.H. & Yang, P.S. 2000. Community structure and functional organization of aquatic insects in an agricultural mountain of Taiwan: 1985-1986 and 1995-1996. *Zoological Studies* 39: 191-202.

Simôes, S.D., Moreira, S., Bisinori, A.B., Gimenez, M.C. & Yabe, J.M.S. 2008. Water quality index as a simple indicator of aquaculture effects on aquatic bodies. *Ecological Indicator* 8: 476-484.

Sudarso, J., Imroatushshoolikhah, Ibrahim, A., Aisyah, S. & Sari, L. 2020. Evaluasi reha-bilitasi riparian Sungai Ranggeh dengan menggunakan indikator komunitas makrozoobenthos. *Oseanologi dan Limnologi di Indonesia* 5(2): 105-119.

Sudarso, J., Suryono, T., Yoga, G.P., Samir, O., Imroatushshoolikhah & Ibrahim, A. 2021. The impact of anthropogenic activities on benthic macroinvertebrates community in the Ranggeh River. *Journal of Ecological Engineering* 22(5): 179-190.

Thorp, J.H. & Covich, A.P. 1991. *Ecology and Classification of North American Freshwater Invertebrates*. New York: Academic Press. Inc.

Townsend, C.R., Scarsbrook, M.R. & Dolédec, S. 1997. Quantifying disturbance in streams: Alternative measures of disturbance in relation to acroinvertebrate species traits and species richness. *Journal of the North American Benthological Society* 16(3): 531-544.

Vimos-Lojano, D., Hampela, H., Vázquez, R. & Martínez-Capel, F. 2020. Community structure and functional feeding groups of macroinvertebrates in pristine Andean streams under different vegetation cover. *Ecohydrology & Hydrobiology* https://doi.org/10.1016/j.ecohyd.2020.04.004

Vyas, V. & Bhawsar, A. 2013. Benthic community structure in Barna stream network of Narmada River basin. *International Journal of Environmental Biology* 3: 57-63.

Wang, X., Zhang, Y., Tan, X., Zheng, Y. & Zhang, Q. 2020. Do water quality, land use, or benthic diatoms drive macroinvertebrate functional feeding groups in a subtropical mountain stream? *Inland Waters* 11(1): 67-77. https://doi.org/10.1080/20442041.2020

Watts, J. 2010. Chinese farms cause more pollution than factories, says official survey. http://www.guardian.co.uk/environment/2010/feb/09/china-farmspollution. Accessed on 20 June 2012.

Weliange, W.S., Leichtfried, M., Amarasinghe, U.S. & Füreder, L. 2017. Longitudinal variation of benthic macroinvertebrate communities in two contrasting tropical streams in Sri Lanka. *International Review of Hydrobiology* 2017: 1-13. DOI: 10.1002/iroh.201601865.

Yoshimura, C., Tockner, K., Omura, T. & Moog, O. 2006. Species diversity and functional assessment of macroinvertebrate communities in Austrian rivers. *Limnology* 7: 63-74.

Yule, C.M. & Sen, Y.H. 2004. *Freshwater Invertebrates of the Malaysian Region*. Academy Science. Malaysia. p. 861.

*Corresponding author; email: yoyo@limnologi.lipi.go.id

APPENDIX 1. Composition and FFG of macroinvertebrate benthic organisms at each observation station

Group	Taxa	FFG	SR1	SR2	SR3	SR4
Plecoptera	Neoperla sp.	Predator	√	√	√	
Plecoptera	Indonemoura	Predator	√			
Plecoptera	Amphinemura	Predator	√	√		
Trichoptera	Ceratopsyche cf ventura	Collector-filterer	√	√	√	√
Trichoptera	Hydropsyche sp.	Collector-filterer	√	√		
Trichoptera	Cheumatopsyche	Collector-filterer	√	√	√	√
Trichoptera	Hydropsychidae 1	Collector-filterer	√			
Trichoptera	Hydromanicus	Collector-filterer		√		
Trichoptera	Agapetus	Scraper	√	√	√	
Trichoptera	Tinodes	Scraper	√			
Trichoptera	Lepidostoma cf hirtum	shreadder	√	√		
Trichoptera	Brachycentrus	Collector-filterer		√		
Trichoptera	Wormaldia	Collector-filterer				√
Trichoptera	Hydroptila	Scraper			√	
Trichoptera	cf. Erotesis	Collector-gatherer			√	
Trichoptera	Oecetis	Predator				√
Trichoptera	Notoperata	Collector-gatherer				√
Ephemeroptera	Platybaetis gagadjuensis	Collector-gatherer	√	√	√	√
Ephemeroptera	Baetis sp.	Collector-gatherer	√	√	√	√
Ephemeroptera	cf. Tricorythodes	Collector-gatherer	√			
Ephemeroptera	cf. Caenis	Collector-gatherer		√	√	√
Lepidoptera	Eoophyla	shreadder	√	√	√	√
Odonata	Hydrobasileus sp.	Predator	√			
Odonata	cf.Zyxomma	Predator		√		
Odonata	Anax cf. geogius	Predator	√			
Odonata	cf. Macromia	Predator	√			
Odonata	cf. Erpetogomphus	Predator	√			
Coleoptera	simsonia longipes	Scraper	√	√		
Coleoptera	Simsonia leai	Scraper			√	
Coleoptera	cf. Stenelmis	Scraper	√		√	

Coleoptera	cf. Ancyronyx	Omnivor			√	
Coleoptera	cf. Microcylloepus	shreadder				
Coleoptera	Elmomorphus sp.	shreadder	√	√	√	
Coleoptera	Cercyon sp.	Predator	√			
Coleoptera	Berosus sp.	Predator	√			√
Coleoptera	cf Helophorus sp.	shreadder	√			
Diptera	Prosimulium	Collector-filterer	√	√		
Diptera	Greniera	Collector-filterer		√	√	√
Diptera	cf. Monopelopia	Predator	√	√	√	√
Diptera	Tanypodinae 1	Predator			√	√
Diptera	Polypedilum	shreadder	√	√	√	√
Diptera	Tanytarsus	Collector-filterer			√	√
Diptera	Eukiefferiella	Collector-gatherer			√	√
Diptera	Orthocladius	Collector-gatherer			√	√
Diptera	Nanocladius	Collector-gatherer			√	√
Diptera	Parakiefferiella	Collector-gatherer			√	√
Diptera	Orthocladiinae6	Collector-gatherer			√	√
Diptera	Rheocricotopus	Collector-gatherer				√
Diptera	Chironomus	Collector-gatherer			√	√
Diptera	Rheotanytarsus	Collector-filterer			√	√
Oligochaeta	Pristina synclites	Collector-gatherer			√	√
Oligochaeta	Pristina menoni	Collector-gatherer			√	
Oligochaeta	Dero (dero) digitata	Collector-gatherer			√	√
Hemiptera	Micronecta	Predator			√	√