IMPACTS OF ENVIRONMENTAL VARIABLES ON MACROINVERTEBRATE FUNCTIONAL FEEDING GROUPS AND BIODIVERSITY IN A MULING RIVER WETLAND FROM NORTHEAST CHINA

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Abstract. Muling River is the fifth-largest river in Heilongjiang Province, and it is also the main feeding river to the Ussuri River which is the boundary river of China and Russia in Heilongjiang Province northeast China. The Muling River basin is in the south of Sanjiang Plain. Macroinvertebrate samples were collected using a D-frame net and Shannon-Wiener index was calculated in terms of abundance. A total of 158 genera or species macroinvertebrates were collected from the 28 sampling sites and classified into six functional feeding groups including 61 gatherers / collectors, 42 predators, 22 scrapers, 14 shredders, 11 filterers / collectors and 8 omnivores. The correlation and relationship between environmental variables and macroinvertebrate functional feeding groups were explored using Pearson analysis and redundancy analysis. Temperature was associated with macroinvertebrates abundance, and nutrients were the main influence factors in Muling River basin.

Keywords: *Muling River basin, macroinvertebrate, community structure, influencing factors, RDA*

Introduction

Functions of river ecosystem research mostly carried out based on the traditional classification of species. However, recent studies have shown that ecosystem functions are mainly subject to the diversity of functional traits, i.e. the distribution of functional traits and the spatial-temporal pattern of abundance (Elliott and Quintino, 2010). Functional traits are sensitive to environmental changes and play a key role in the study of the relationship between biodiversity and ecosystem functions. Functional diversity based on biological traits is closely related to ecosystem processes and is the key to understand ecosystem and community functions (Jiang et al., 2018). Macroinvertebrates were widely used to monitor the damage of aquatic ecosystem, and they are also an

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important part of aquatic food web, which is the basis of nutrient cycle and ecological balance of ecosystem (Mangadze et al., 2016). Many factors have caused damage to the aquatic ecosystem in the Muling River basin, and the importance of monitoring water quality in the Muling River basin through macroinvertebrate is self-evident. The species characteristics of functional groups are more closely related to the environment, which can more directly reflect the ecological process of the ecological environment affecting aquatic communities, and better understand the water ecosystem and its biodiversity (An et al., 2017; Liu et al., 2019). In the river ecosystem, the functional diversity of macroinvertebrate can better reflect the ecosystem functions than community structure. Many studies have shown that substrate type and aquatic vascular plants are affecting the growth and functional group distribution of macroinvertebrate (Hubler et al., 2016; Ding et al., 2017; Kaskela et al., 2017).

Muling River is the fifth-largest river in Heilongjiang Province, and it is also the main feeding river to the Ussuri River which is the boundary river of China and Russia (Li et al., 2016). The approximately length of the Muling River is 834 km with annual water flows of 2.35 billion m^3. The river flows through five counties or cities of Muling, Jixi, Jidong, Mishan and Hulin from the south to the northeast of Heilongjiang Province (Li et al., 2015). Upstream of the river is characterized by temperate continental climate with a hot summer rainy and long cold winter. The annual average precipitation in the upstream is 530 mm and mainly occurs from July to September. In the midstream, the climate is temperate and semi-humid monsoonal with annual average temperature of 3.1°C (-18°C ~ 21°C). The annual precipitation is 522 mm and the frost-free period is 149 days. At downstream area, the climate is characterized by temperate continental monsoonal. In recent years, with the aggravation of agricultural non-point source pollution, industrial discharge pollution and urban living pollution in Muling River Basin, the water quality of Muling River is deteriorating, which has had a negative impact on the local people's production and life.

This study aimed to collect macroinvertebrate fauna, and explore the relationships between macroinvertebrate functional feeding groups and environmental variables in the wetland environments of Muling River basin.

Materials and methods

Study area

Muling River basin located in the south of Sanjiang Plain with an area of 18427 km^2, and it is the fifth-largest river in Heilongjiang Province northeast of China, which is the main feeding river to the Ussuri River the boundary river of China and Russia (*Fig. 1*). According to the manual of inland waters fishery natural resources investigation (Zhang and He, 1991), and principles to the requirement of sampling sites, in combination with climatic characteristics and natural form of Muling River basin, 28 sampling sites were selected from upstream, midstream to downstream (*Table 1*).

Environmental variables data sampling

Samples were collected 3 times from 28 sampling sites of Muling River basin in May (spring), July (summer) and September (autumn) periods in 2015. Water transparency (SD) and water depth (WD) were measured in the field using a Secchi disk and graduated portable staff gauge, respectively. Electric conductivity (EC), dissolved oxygen (DO), pH and water temperature (T) also measured in the field using a portable multi-probe (YSI 6600, YSI Inc., USA). We used the Chinese standard methods proposed by Ministry of Environmental Protection of People's Republic of China (Standard, 2002) to determine the concentration of total nitrogen (TN), total phosphorus (TP), N:P ratio (N:P), ammonium nitrogen (NH_4^+-N), nitrate nitrogen (NO_3^--N), chemical oxygen demand (COD_{Mn}).

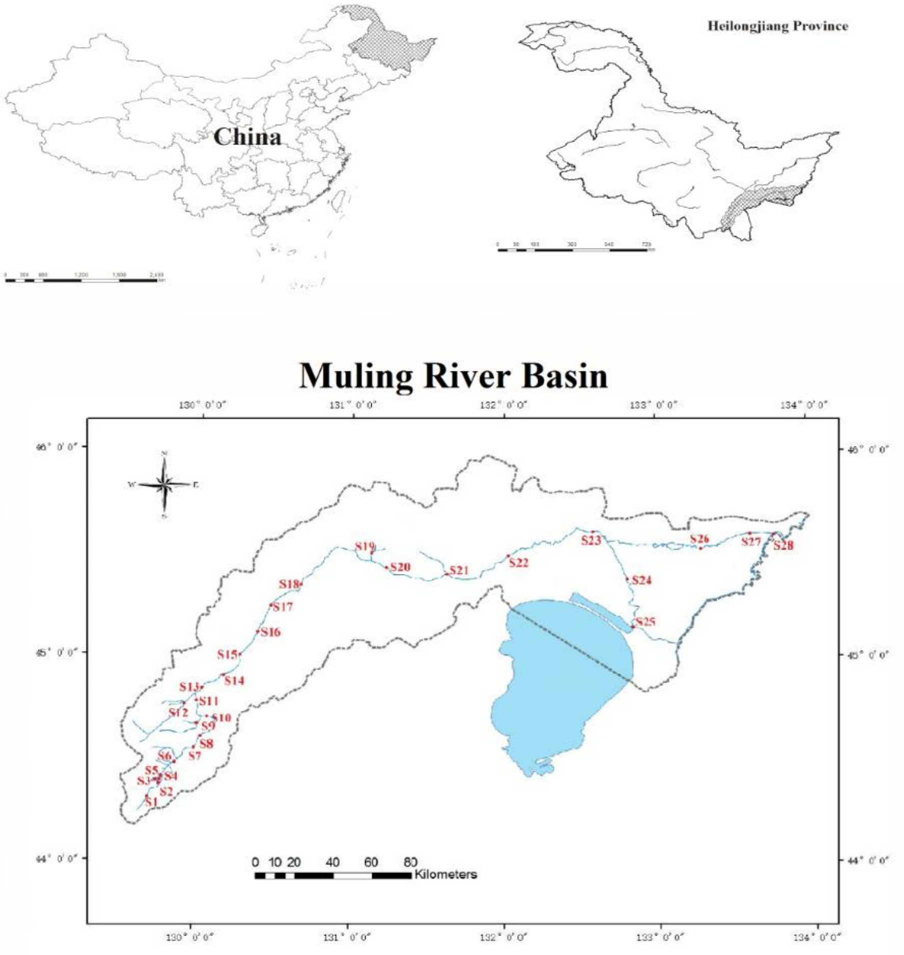

Figure 1. Location of 28 sampling sites in Muling River basin

Macroinvertebrate data sampling

Three random subsamples were collected at locations of 1 m^2 at each sampling site by using a D-frame net (0.25-mm, 60 mesh). All macroinvertebrate samples were composited into a single sample, preserved in 75% ethanol and transported to the laboratory for identification. In the laboratory, all samples were sorted on white porcelain pans, identified, and counted with a light stereomicroscope (10×, Leica Microsystems, German). All individuals were identified to genus or species using appropriate identification guides (Morse et al., 1994; Epler, 2001). Taxa were divided into six functional feeding groups according to Cummins (1974) and Duan et al. (2010): predators (PR), omnivores (OM), gatherers/collectors (GC), filterers/collectors (FC), scrapers (SC) and shredders (SH) (Cummins, 1974; Duan et al., 2010).

Table 1. *The sampling stations and coordinates in Muling River basin*

Sampling sites	Latitude (N)	Longitude (E)
S1	44°01′48″	130°11′24″
S2	44°03′36″	130°10′48″
S3	44°03′00″	130°09′36″
S4	44°04′12″	130°10′48″
S5	44°04′48″	130°10′48″
S6	44°11′24″	130°15′36″
S7	44°13′12″	130°15′00″
S8	44°13′48″	130°15′36″
S9	44°21′36″	130°16′48″
S10	44°24′36″	130°19′12″
S11	44°28′12″	130°14′24″
S12	44°28′12″	130°12′36″
S13	44°29′24″	130°13′48″
S14	44°34′48″	130°19′48″
S15	44°40′12″	130°26′24″
S16	44°53′24″	130°30′36″
S17	45°00′00″	130°32′24″
S18	45°04′48″	130°40′12″
S19	45°18′00″	131°00′36″
S20	45°18′00″	131°03′36″
S21	45°20′24″	131°31′48″
S22	45°27′00″	131°52′12″
S23	45°42′00″	132°25′12″
S24	45°35′24″	132°36′36″
S25	45°19′48″	132°48′36″
S26	45°44′24″	132°57′00″
S27	45°45′36″	133°06′00″
S28	45°58′12″	133°40′12″

Statistical analyses

Variation of environmental variables and abundance of functional groups in different sampling periods were analyzed using One-way ANOVA in SPSS 19.0 software. Before analysis, the data was lg(x+1) transformed to manage variance heterogeneity and ensure the data is normally distributed. In this study, the gradient length of the first ordination axis was 0.404 in the detrended correspondence analysis (DCA). Therefore, redundancy analysis (RDA) with Monte Carlo simulations (499 permutations) ordination based on unimodal method was selected to analyze the relation by using CANOCO for Windows 4.5 software (Microcomputer Power, New York, USA). Pearson correlation analysis was carried out to confirm the significant relationships between environmental variables and the abundance of functional feeding group. Cluster analyses was conducted using the PRIMER 7 software package (Clarke and Gorley, 2015).

Diversity of macroinvertebrate FFGs was represented by Shannon-Wiener index (Shannon and Wiener, 1949) as follows:

$$H' = -\sum_{i=1}^{s} P_i \log_2 P_i \tag{Eq.1}$$

where, S is the number of FFGs within the given sample; and P_i is the percentage of FFGs i in the total number of individuals.

Results

Environmental variables

Among all sampling sties, natural gradients (e.g., dissolved oxygen and temperature) and nutrient indicators (e.g., total phosphorus, N:P ratio, ammonium nitrogen and nitrate nitrogen) were not significantly different ($p > 0.05$), but water transparency, water depth, electric conductivity, total nitrogen and chemical oxygen demand were significantly different ($p < 0.01$) (*Table 2*).

Table 2. *One-Way ANOVA of environmental variables and macroinvertebrate FFGs abundance. Data are average values (with SE). Environmental variables: water transparency (SD), water depth (WD), electric conductivity (EC), dissolved oxygen (DO), pH, water temperature (T), total nitrogen (TN), total phosphorus (TP), N:P ratio (N:P), ammonium nitrogen (NH_4^+-N), nitrate nitrogen (NO_3^--N), chemical oxygen demand (COD_{Mn}). Macroinvertebrate FFGs: predators (PR), omnivores (OM), gatherers/collectors (GC), filterers/collectors (FC), scrapers (SC) and shredders (SH). F-value and P-value from One-way ANOVA by post-hoc test using Tukey HSD ANOVA*

	2015May	**2015Jul.**	**2015Sep.**	***F***	***p*-value**
Environmental variables					
SD (m)	0.35(0.05)	0.32(0.07)	0.48(0.07)	10.418	0.000**
WD (m)	2.72(0.76)	3.13(1.04)	3.02(1.04)	75.232	0.000**
EC (ms/cm)	0.15(0.01)	0.15(0.01)	0.21(0.02)	2.472	0.002**
DO (mg/L)	7.45(0.29)	8.73(0.29)	7.49(0.56)	1.676	0.052
pH	7.42(0.12)	7.03(0.26)	7.99(0.06)	1.903	0.021*
T (°C)	14.81(0.47)	22.26(0.55)	6.89(0.43)	0.215	0.862
TN (mg/L)	1.73(0.14)	1.99(0.21)	1.62(0.16)	2.662	0.001**
TP (mg/L)	0.6(0.05)	0.69(0.04)	0.36(0.03)	0.456	0.986
N:P	3.86(0.56)	3.13(0.35)	6.56(1.6)	0.727	0.815
NH_4^+-N (mg/L)	0.22(0.02)	0.35(0.04)	0.13(0.01)	0.704	0.839
NO_3^--N (mg/L)	0.58(0.07)	1.52(0.5)	0.28(0.03)	1.143	0.329
COD_{Mn} (mg/L)	3.8(0.13)	3.98(0.1)	4.06(0.12)	3.410	0.000**
FFGs abundance					
PR (ind./m^2)	25.75(3.47)	46.75(2.68)	24.54(2.6)	0.614	0.916
OM (ind./m^2)	12.14(3.03)	5.68(0.85)	5.82(1.1)	0.701	0.842
GC (ind./m^2)	60.14(5.94)	114.54(6.51)	36.46(2.92)	0.351	0.998
FC (ind./m^2)	10.93(2.6)	11.86(2.02)	6.5(1.22)	1.615	0.065
SC (ind./m^2)	38.93(12.36)	30.46(4.67)	17.75(2.22)	2.335	0.004**
SH (ind./m^2)	6.68(1.66)	16.5(2.11)	11.54(2.62)	0.754	0.787
Total (ind./m^2)	154.57(14.29)	225.79(8.52)	102.61(6.2)	0.535	0.946
Shannon-Wiener (*H'*)	1.69(0.06)	1.85(0.04)	2.03(0.04)	0.566	0.961

*$P<0.05$, **$P<0.01$

Macroinvertebrate functional feeding groups

During the sampling periods, a total of 13523 macroinvertebrate individuals belonging to 46 families 158 genera or species were identified from the study area, consisting of 61 gatherers/collectors, 42 predators, 22 scrapers, 14 shredders, 11 filterers/collectors and 8 omnivores (*Appendix A*). All FFGs, total abundance and Shannon-Wiener index were not significantly different ($p > 0.05$), while SC group was significantly different ($p < 0.01$) (*Table 1, Fig. 2*). Highest abundance of total macroinvertebrate was observed in summer, while the maximum value of Shannon-Wiener index presented in autumn (*Fig. 3*).

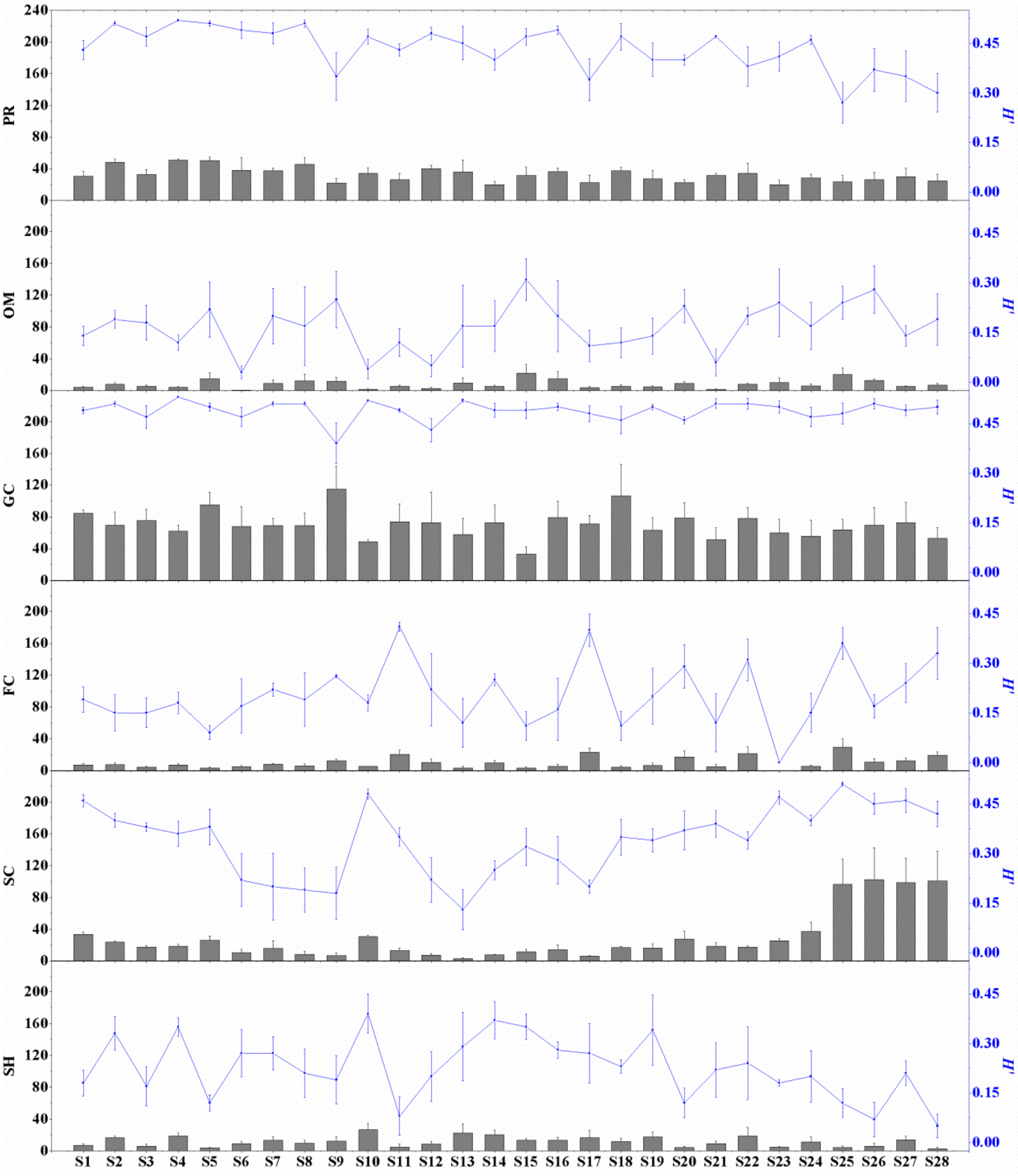

Figure 2. *Macroinvertebrate FFGs abundance (ind./m^2) among sampling sites. Macroinvertebrate FFGs: predators (PR), omnivores (OM), gatherers/collectors (GC), filterers/collectors (FC), scrapers (SC) and shredders (SH)*

Correlation analysis

Correlation analysis indicated that temperature was associated with all FFGs abundance ($p < 0.01$ or $p < 0.05$). By contrast, SD was negative significantly correlated with group FC ($p < 0.05$) and SH ($p < 0.05$) and DO displayed negative correlations with group PR ($p < 0.05$) and SH ($p < 0.01$). The pH value negatively correlated with group GC ($p < 0.01$) and SC ($p < 0.01$). However, WD, TN, TP and NH_4^+-N were only positive significantly correlated with one group, such as PR ($p < 0.05$), SH ($p < 0.01$) and GC ($p < 0.01$), respectively. While N:P ratio was negative significantly correlated with group GC ($p < 0.05$). COD_{Mn} positively correlated with group PR ($p < 0.01$) and SH ($p < 0.01$) and negatively correlated with group SC ($p < 0.05$).

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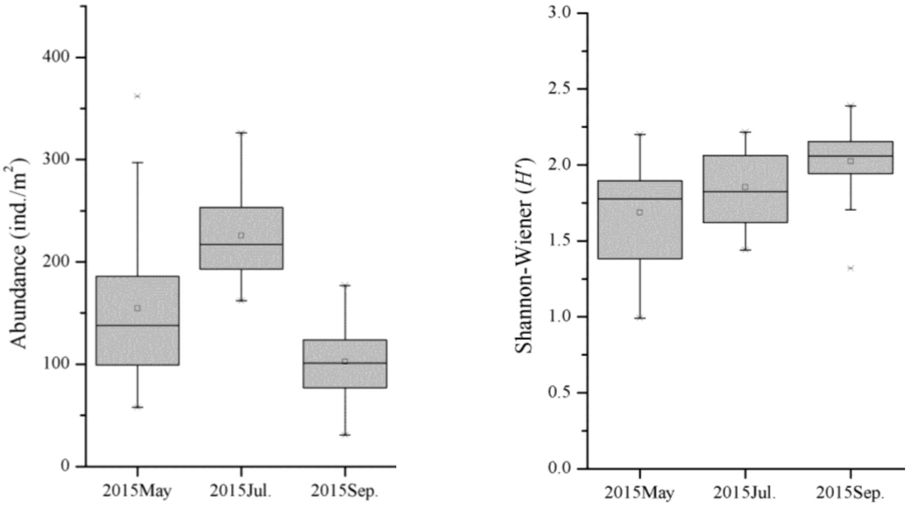

Figure 3. *Boxplots of macroinvertebrate abundance and Shannon-Wiener index among seasons*

On the other hand, environmental variables of WD, DO and N:P positively correlated with biodiversity index (*H'*) of PR, SH and GC groups, respectively. TP was both negatively correlated with group GC and SC biodiversity index. COD_{Mn} was positively correlated with group PR biodiversity index, while negatively correlated with group OM (*Table 3*).

Table 3. *Correlation (Pearson) analysis between functional feeding groups abundance (ind./m^2), Shannon-Wiener index (H') and environmental variables. Some variables without any significant correlation were not shown. Environmental variables: water transparency (SD), water depth (WD), electric conductivity (EC), dissolved oxygen (DO), pH, water temperature (T), total nitrogen (TN), total phosphorus (TP), N:P ratio (N:P), ammonium nitrogen (NH_4^+-N), nitrate nitrogen (NO_3^--N), chemical oxygen demand (COD_{Mn}). Macroinvertebrate FFGs: predators (PR), omnivores (OM), gatherers/collectors (GC), filterers/collectors (FC), scrapers (SC) and shredders (SH)*

	Abundance						***H'***				
	PR	**OM**	**GC**	**FC**	**SC**	**SH**	**PR**	**OM**	**GC**	**SC**	**SH**
SD				-0.162*		-0.153*					
WD	0.153*						0.220*				
DO	-0.162*					-0.223**					0.260*
pH			-0.343**		-0.218**						
T	0.477**	0.255**	0.562**	0.303**	0.211**	0.319**					
TN						0.333**					
TP			0.271**						-0.224*	-0.230*	
N:P			-0.155*						0.228*		
NH_4^+-N					0.214**						
COD_{Mn}	0.242**				-0.202**	0.280**	0.274*	-0.218*			

*$P<0.05$, **$P<0.01$

RDA analysis

Redundancy analysis (RDA) revealed clear clusters of sampling sites by macroinvertebrate abundance and environmental variables (*Fig. 4*), with several outliers (S2, S25 and S28). The results of Monte Carlo test revealed that the first canonical axis and all canonical axes were significantly different (F = 13.781, p = 0.002; F = 2.247, p = 0.004, respectively), indicating associations between macroinvertebrate FFGs and environmental variables existed. The first two axes of FFGs correlations to environmental variables were 0.91 and 0.761, which combined explained 87.4% of FFGs-environment relationship. In RDA biplot, TN and N:P had high inflation factors. Group SC and OM mainly impacted by T and NH_4^+-N at S26 and S27, and group GC and PR positively correlated with EC, WD and SD at S3, S4, S5, S20 and S24. Meanwhile, group SH has a positive correlation with TN, N:P and NO_3^--N at S6, S15, S21, S22 and S23. We also found that pH, DO and COD_{Mn} were the main factors at S7~S14, S16, S17 and S19.

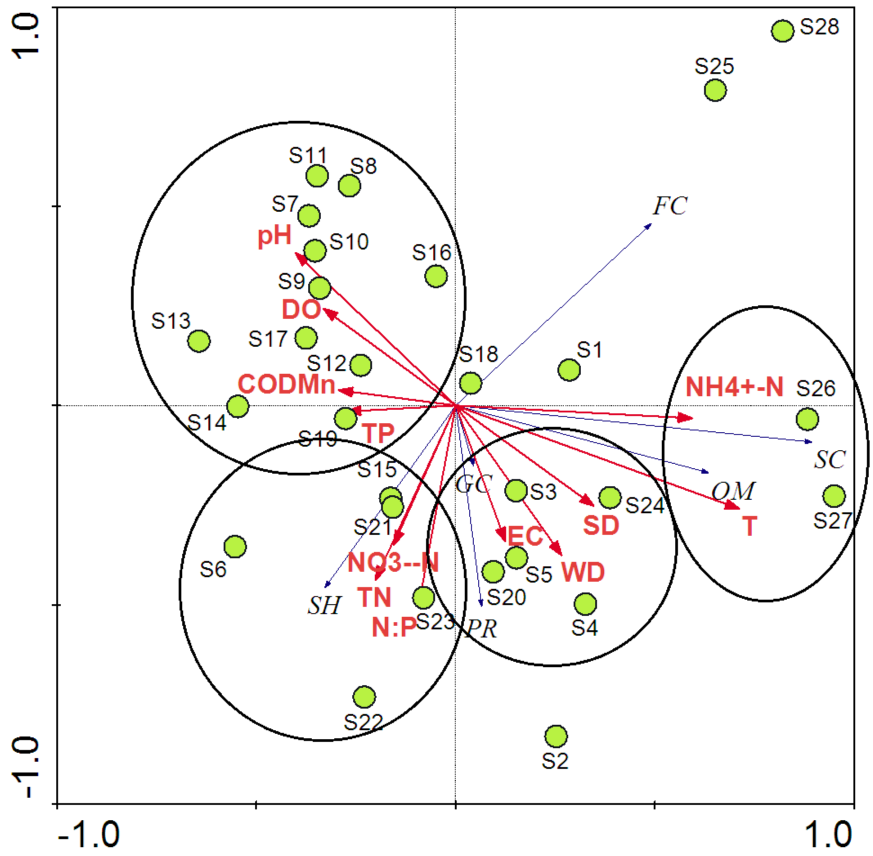

Figure 4. *RDA biplot of macroinvertebrate FFGs abundance and environmental variables with sampling sites in Muling River basin. Environmental variables: water transparency (SD), water depth (WD), electric conductivity (EC), dissolved oxygen (DO), pH, water temperature (T), total nitrogen (TN), total phosphorus (TP), N:P ratio (N:P), ammonium nitrogen (NH_4^+-N), nitrate nitrogen (NO_3^--N), chemical oxygen demand (COD_{Mn}). Macroinvertebrate FFGs: predators (PR), omnivores (OM), gatherers/collectors (GC), filterers/collectors (FC), scrapers (SC) and shredders (SH)*

Discussion

Functional groups can respond to changes in living environment and have a certain impact on ecosystem functions (Jia and Du, 2014). The difference of abundance is the result of habitat filtering, that is, the rank character with higher abundance can be considered as the character with better adaptability to regional environment (Menezes et al., 2010). Ecosystem function is essentially dependent on the functional group of the species, and which has become a powerful and reliable method to study the dynamic change of community by functional characters (Hooper and Vitousek, 1997; Diaz et al., 2004; Jiang et al., 2008). The large difference in spatial pattern of functional groups is the response to environmental changes and the tradeoff between different functions.

Globally, changes in land use, especially loss of riparian forests, can lead to a reduction or change in the structure, function and diversity of macroinvertebrate in some river basin (Allan, 2004; Benstead and Pringle, 2004; Jinggut et al., 2012). Once the riparian zone lacks the shelter of riverside forest, the sun will direct to the water surface and cause the water temperature to rise. Because the water temperature is close to the heat-resistant limit in tropical areas, some species of macroinvertebrate adapted to cold water cannot survive (Irons et al., 1994; Boyero et al., 2012). Moreover, the decrease of leaf litter is the main food source of shredders, which will block the growth and development of group SH and make the aquatic ecosystem unbalanced, and ultimately affect the structure and function of the ecosystem (Liu et al., 2019). Serious soil erosion in Muling River Basin, soil and water loss in riparian zones causes large amounts of sediment to enter rivers. The surface of river sediment is covered by muddy soil, which affects the growth of algae (Jia et al., 2009; Jiang et al., 2018). At the same time, these sediments will also adhere to the surface of the body, trachea, and gill of the macroinvertebrate, which leading to the disappearance of macroinvertebrate (Magbanua et al., 2013).

In this study, we demonstrated the impacts of environmental variables on macroinvertebrate feeding functional groups. No significant differences in the FFGs were observed along season gradient, except group SC (*Table 1*). Mollusk (group SC) dominated at sampling sites of S25~S28 in the downstream of river, which close to floodplain wetlands along Ussuri River. Guan et al. (2017) sampled macroinvertebrate assemblages along Wusuli River (upstream, midstream, and downstream), and agreed with the emerging theory suggesting that aquatic invertebrate assemblages in floodplain wetlands should change longitudinally along a river’s length and be affected by lateral connectivity of floodplain habitats with main river channels (Guan et al., 2017). Wu et al. (2017) found that snails could be possess several attributes that should make them useful as potential environmental indicators in Sanjiang Plain, and the certain snail species may provide a robust and rapid indicator of environmental impacts in freshwater in Heilongjiang Province of China (Wu et al., 2017). Next year, Guan et al. (2018) also confirmed that the snails (Mollusca: Gastropoda) can rapid assessments of wetland condition using aquatic invertebrates simple effective in northeastern China (Guan et al., 2018).

Macroinvertebrate community structure is usually determined by the physical structure and complexity of the habitat (Rennie and Jackson, 2005). Aquatic vascular plants play an important role in structuring macroinvertebrate species and selecting species related to functional groups dynamics and feeding habits (Valinoti et al., 2011; Gleason et al., 2018). The distribution of macroinvertebrate is also determined by vegetation type, especially the structure and growth form of aquatic vascular plants (Rennie and Jackson, 2005). Aquatic vascular plants affect the underwater climate and chemical properties by absorbing and releasing chemical substances (such as nutrients and antagonistic substances) (Valk and Arnold, 2010). However, as the growth of aquatic vascular plants in northern China is mainly affected by seasonal temperature changes, dominant communities can only be formed in summer and autumn (Liu et al., 2019).

In spring, the farmland near the Muling River basin contains a lot of nutrients (nitrogen and phosphorus) in the sediment of pesticide and chemical fertilizers. Chen et al. (2019)

studies have shown that nitrogen can enter the water body through fish secretion and excretion (Chen et al., 2019). Nitrogen-containing nutrients in the water body are absorbed by algae growth and carried down together through surface runoff to provide sufficient nutrients for the growth of plankton. Meanwhile, greatly increased the number of plankton which as the source of food for macroinvertebrate, such as group SH positively correlated with TN (*Table 2*).

Moreover, iron, as an element affecting chlorophyll synthesis in plants, is also a trace element needed for phytoplankton growth (Zhang, 2015). Trace element copper is an indispensable metal element for the metabolism of microelements and plants in cell membranes, which can affect the growth of plankton (Zhang et al., 2014). Hydrology is considered the paramount environmental control of freshwater wetlands, with temporary drying being a major constraint on aquatic insects (Wu et al., 2019). The movement group (Liu et al., 2019) of macroinvertebrate could be considered as a new method for monitoring and evaluating water quality in Muling River basin for further studies in the future.

Conclusions

During the three times sampling in Muling River basin, we collected 13523 macroinvertebrate individuals belonging to 46 families 158 genera or species were identified from the study area, consisting of 61 gatherers/collectors, 42 predators, 22 scrapers, 14 shredders, 11 filterers/collectors and 8 omnivores. All FFGs, total abundance and Shannon-Wiener index were not significantly different. Total abundance of macroinvertebrate was higher in summer and biodiversity index was higher in autumn. We found that temperature was associated with all FFGs abundance and nutrients were the main influence factors in Muling River basin. Therefore, controlling the input of nutrients is the key to the ecological environment and aquatic biodiversity protection of the Muling River basin in the future.

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APPENDIX

Appendix A. *Macroinvertebrate community structure and functional feeding groups during the sampling periods. Symbols: relative abundance + (<1%), ++ (1–1.9%), +++ (>2%)*

Family	Genera or species	FFGs	2015 May	2015 July	2015 Sep.
Corixidae	*Corixa substriata*	PR	++	++	+
	Hesperocoixa distani	PR		+	
	Hesperocorixa kirkaldy	PR	+		
	Sigra distanti	PR		+	
Tipulidae	*Hexatoma* sp.	PR	+		
	Nippotipula sp.	SH	+	++	+++
	Erioptera sp.	GC	+	+	+
	Pilaria sp.	PR		+	
Chironomidae	*Diplocladius* sp.	GC	++	++	+
	Heterotrissocladius sp.	GC		+	
	Eukiefferiella fuldensis	GC		+	
	Synorthocladius semivirens	GC		++	
	Orthocladius roussellae	GC		+	
	Orthocladius sp.	GC		+	+
	Orrhocladius thienemanni	GC		+	
	Orrhocladius vaillanti	GC		+++	
	Thienemannia gracilis	GC	+	+	++
	Chironomus kiiensisTokunaga	GC	+++	+++	++
	Chironomus flaviplumus	GC	+++	+	+
	Chironomus dorsalis	GC		++	
	Chaetocladius sp.	GC		++	
	Chironomus plumosus	OM	+	+	++
	Cryptochironomus maculipennis	PR	++	++	+
	Parachironomus arcnatus	PR	+	++	+
	Eukiefferiella fittkaui	GC	++	+++	++
	Eukiefferiella fuldensis	GC	+	++	+
	Eukiefferiella sp.	GC		++	
	Eukiefferiella gracei	GC		+	
	Parakiefferiella sp.	GC		+	+
	Dicrotendipes nigrocephalicus	GC	++	++	
	Dicrotendipes pelochloris	GC	++	+++	+
	Dicrotendipes tamaviridis	GC	++	+	
	Dicrotendipus lobifer	GC		++	
	Smittia sp.	GC	+++	++	+
	Pseudosmittia sp.1	GC	+		+
	Pseudosmittia sp.2	GC		+	++
	Polypedilum nubeculosum	SH	+	+	
	Polypedilum laetum	SH	+	++	
	Polypedilum sordens	SH	+	+	++
	Polypedilum scalaenum	SH		+	
	Polypedilum nubifer	SH			

Family	Genera or species	FFGs	2015 May	2015 July	2015 Sep.
	Cricotopus vierriensis	SH			+++
	Cricotopus bicinctus	SH			+
	Zalutschia sp.	SH		+	
	Apsectrotanypus sp.	PR	+++	+	++
	Glyptotendipes pallens	FC		+	
	Glyptotendipes gripekoveni	FC		+	
	Glyptotendipes tokunagai	FC		+	
	Stictochironomus maculipennis	OM	+		+
	Stictochironomus akizukii	OM	+++	+	+
	Stictochironomus sp.A.	OM	+++	+	++
	Stictochironomus sp.B.	OM	+	+	+
	Stictochironomus caffrarius	OM			
	Paracladopelma undine	GC	+	+	+
	Paracladopelma nigritula	GC	+	+	+
	Chironomus anthracinus	GC	++	+	++
	Harnischia fuscimana	GC	++	+	
	Micropsectra chuzeprima	GC	+	+	++
	Tanypus sp.	PR		+	+++
	Tanypus villipennis	PR	+	+	
	Cladotanytarsus vanderwulpi	GC		+	
	Tanytarsus mendex	FC	+	+	++
	Tanytarsus chinyensis	FC	+++	+	+
	Tanytarsus signatus	FC	+		
Ephemeridae	*Ephemera shengmi*	GC	+	+	
	Ephemera nigroptera	GC	+		
Heptageniidae	*Heptagenia* sp.	SC	++	+	
Ephemerelliae	*Ephemerella nigra*	GC	+	+	
	Ephemerellidae serratella	GC		+	
	Ephemerella fusongensis	GC	+		
Baetidae	*Baetis* sp.	GC	+	+	
	Baetis thermicus	GC		+	
Leptophlebiidae	*Leptophlebia* sp.	GC		+	
	Paraleptophlebia sp.	GC		+	
	Thraulus sp.	GC		+	
Siphlonuridae	*Ameletus montanus*	GC		+	
Potamanthidae	*Potamanthidae* sp.	GC	+		
Chloroperlidae	*Alloperla sapporoensis*	PR	+	+	
	Alloperla nikkoensis	PR	+		
Pteronarcyidae	*Pteronarys* sp.	PR		+	
Pelidae	*Paragnetina* sp.	PR	++	+	
	Cyamia sp.	PR	+	+	
	Agnetina sp.	PR		+	
Perlodidae	*Hydroperla japonica*	PR			
Peltoperlidae	*Perlomyer* sp.	SH	+	+	
Taeniopterygidae	*Doddsia iaponica*	SH		+	
Hydropsychidae	*Hydropsyche* sp.	FC	+	+	+

Family	Genera or species	FFGs	2015 May	2015 July	2015 Sep.
	Hydropsyche nakaharai	FC	+++		
Hydroptilldae	*Hydroptila* sp.	SC	+	+	+
Polycentropodidae	*Polycentropus* sp.	FC	+	++	++
Goeridae	*Goera ramosa*	SC	+	+	++
	Goera kyotonis	SC	+	+	
Stenopsychidae	*Parastenopsyche* sp.	GC		+	
Rhyacophilidae	*Rhyacophila* sp.	PR	+	+	
Limnephilidae	*Apatania* sp.	SC	+	+	+
	Neophylax sp.	SC		++	+++
	Stenophylax koizumii	SH		+	
	Glyphotaelius admorsus	SH	++		
	Stenophylax koizumii	SH	+		
Libellulidae	*Epiophcetia superstes*	PR	+	+	++
Petaluridae	*Tanypteryx pryeri*	PR		+	++
Macromiidae	*Macromidae* sp.	PR		+	
Libellulidae	*Hydrobasileus* sp.	PR	+	+	
Comphidae	*Davidius nanus*	PR		+	+
	Cercion sieboldii	PR		+	
	Gomphus postocularis	PR			+
	Ictinogomphus sp.	PR		+	
Gomphidae	*Anisogomphus* sp.	PR	+	+	
Lestidae	*Lestes* sp.	PR		+	
Agriidae	*Nenrobasis* sp.	PR		+	+++
	Calopteryx cornecia	PR			+
Dytiscidae	*Cybister japonicus*	PR	+	+	+
Noteridae	*Noterus* sp.	PR		+	
Carabidae	*Chlaenius* sp.	PR		+	++
Hydrophilidae	*Hydrophilus acuminatus*	PR	+	+	
Glossiphoniidae	*Helobdella nuda*	PR	+	+	+
	Batracobdella paludosa	PR	++		+
	Glossiphonia heteroclita	PR	++	+	+
	Parabdella quadrioculata	PR		+	+
	Glossiphonia complanata	PR			
	Glossiphonia lata	PR		+	++
	Whitmania sp.	PR		+	++
Tubificinae	*Limnodrilus hoffmeisteri*	GC	++	++	++
	Limnodrilus claparedeianus	GC	+	+	++
	Limnodrilus helveticus	GC	+	+	+
	Limnodrilus udekemianus	GC	++		
	Limnodrilus amblysetus	GC	+	+	+
	Aulodrilus bretscher	GC		+	+
	Aulodrilus pigueti	GC		+	+
	Branchiura sowerbyi	GC	++	+	+
	Tubifex tubifex	GC	++	+	+
	Spirosperma nikolskyi	GC		+	+++
Enchytraeidae	*Henlea* sp.	GC		+	

Family	Genera or species	FFGs	2015 May	2015 July	2015 Sep.
Naididae	*Nais variabilis*	GC	++	+	+
	Nais communis	GC	+	+	+
	Nais simplex	GC	+	+	
	Slavina sp.	GC	+		+
	Dero sp.	GC	+		
Melaniidae	*Semisulcospira amurensis*	SC	+++	++	++
	Semisulcospira cancellata	SC	++	+	+
Viviparidae	*Bellamya purrificata*	SC	++	+	++
	Viviparus chui	SC	+	+	+
	Cipangopaludina Chinensis	SC	++	+	+
	Cipangopaludina ussuriensis	SC	+	+	+
Hydrobiidae	*Parafossarulus striatus*	SC	++	+	+
Lymnaeidae	*Lymnaea stagnalis*	SC	++	+	+
	Radix auricularia	SC	+	+	++
	Radix plicatula	SC	+	+	+
	Radix swinhoei	SC	++	+	+
	Radix ovata	SC	++	+	+
	Radix lagotis	SC	++	+	+
	Galba pervia	SC	+++	+	+
	Galba truncatula	SC	+	+	+
Planoribidae	*Polypylis hemisphaerula*	SC	++	+	+
Unionidae	*Unio douglasiae*	FC	+	+	+
	Lanceolaria grayana	FC	+	+	+
Palaemonidae	*Exopalaemon modestus*	OM	+	+	+
	Palaemon sinensis	OM	+	+	+