Advances in selection mechanism of aquatic insects on water flow velocity and substrate in small mountain rivers

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Abstract: As a major group of macroinvertebrate benthos, aquatic insects can reflect the status of river ecosystem to a great extent, and are one of the important biological monitoring indicators. Sediment and flow velocity are very important environmental factors which can affect community structure and biological characteristics of aquatic insects in rivers. However, there were few studies on the relationship between benthos and the two factors at home and abroad. In future, it is suggested to use physical model to simulate and construct the coupling relationship between diversity index of aquatic insects, flow velocity and sediment, and can reveal the selection mechanism of aquatic insects on velocity and sediment, so as to provide scientific basis for the protection and restoration of aquatic habitat of small rivers in mountainous areas.

1. Role of aquatic insects in water ecological monitoring

As a very important group, macroinvertebrate benthos play a vital role in freshwater ecosystem. In the food web, they are the important secondary producers. The life activities of benthos could change the environmental characteristics of habitat to a certain extent, such as promoting the mineralization of nutrients, increasing the dissolved oxygen at the bottom of water, promoting the material exchange at the mud-water interface and accelerating the transfer rate of nutrients, etc. (Wetzel, 2001). Therefore, macroinvertebrate benthos are often regarded as ideal biological monitoring groups.

As a dominant group of macroinvertebrate benthos, especially in the river ecosystem, aquatic insects have the characteristics of large individuals, easy identification, long life span, small activity and range, unique breathing pattern and sensitive to environmental changes. As a consequence, aquatic insects can largely reflect the status of river ecosystem and are often used as one of the main means of biological monitoring.

2. Relationship between environmental factors and aquatic insects

The relationship between environmental factors and macroinvertebrate invertebrates has always been a research hotspot. Many studies have shown that sediment and flow velocity are two important environmental factors, strongly affecting the community structure of macroinvertebrate invertebrates in river ecosystem (Barbour et al., 1999; Sturm et al., 2009; Wang et al., 2007; Duan, 2009). However, in most studies the data were statistically analyzed by using these statistical methods, such as canonical correspondence analysis (CCA) and regression analysis (RA) (Syrovátka et al., 2009; Pan et al., 2008; Jiang et al., 2009). These results only show that sediment and flow velocity are important factors influencing benthos, but the internal reason is still unclear. Therefore, it is necessary to study the effect mechanism of flow velocity and sediment on the community structure of aquatic insects.

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There are few studies on the relationship between aquatic insects and factors such as flow velocity and sediment abroad (Syrovátka et al., 2009; Adámek et al., 2010). In most studies, characteristics of community structure of aquatic insects have been carried out, while the selection mechanism of benthos for flow velocity and sediment has not been studied. The life history and yield of aquatic insects in streams have been studied by Alexander et al. (2000). Skalskaya et al. (2008) have explored the niche and community structure of aquatic insects in small river. It has been indicated that the flow velocity and the particle size of riverbed sediment play a significant role in the ecological distribution of benthos by the statistical research based on CCA and WA (Sturm, 2009).

Similarly, less research work has been done on the relationship between aquatic insects and influencing factors of velocity and sediment in China. Field experiments on the effects of riverbed sediment with five different particle sizes on the diversity of macrobenthos have been conducted and differences of aquatic insect communities in different sediment types were compared by Duan et al. (2007). Most studies have less focused on the relationship between benthos and flow velocity, mainly based on statistical analysis of field survey data (Fu et al., 2008; Zhao and Liu, 2010).

3. Results and discussion

From the perspective of practical application, a large number of diversion type small hydropower stations have been built in small mountain rivers in some southern areas rich in water resources. Deep water and slow flow reservoir habitat appeared in the reservoir area upstream of the barrage of these rivers. The construction of the barrage would reduce the flow of the downstream reach, or even cut off the flow in the downstream of the dam, especially in the dry season.

Because benthic animals have their inherent preference and adaptation to flow velocity and sediment, the construction of water conservancy projects leads to changes in flow velocity and sediment, resulting in great changes in benthic animal resources. A variety of river habitats will lead to changes in the species and community structure of benthic animals. The study on the selection mechanism of benthic animals for flow velocity and sediment will help us to explore the root causes, and put forward more targeted and feasible protection countermeasures when protecting and restoring aquatic ecosystems.

In southern areas of China, small mountain rivers are characteristic of large slopes, abundant rainfall, high coverage of surrounding vegetation, obvious seasonal changes and a wide range of changes in flow velocity and sediment. Moreover, these regions are extremely rich in biodiversity and can be used as ideal natural experimental site for exploring the relationship between benthos and flow velocity and sediment.

Our previous research results were described as follows. The density (ind./m^2) and biomass (g/m^2) of dominant species of aquatic insects in the study river were shown in Table 1. Taking the relative density or relative biomass ≥ 10% as the standard of dominant species, there were seven dominant species of aquatic insects in the study river. The difference of dominant species composition in dry season and wet season was obvious. In the dry season, *Hydrobaenus* sp., *Orthocladius* sp. and *Polypedilum* sp. were dominant in density, while *Hydrobaenus* sp., *Orthocladius* sp. and *Radix* sp. are dominant in biomass. In the tributaries of the investigated rivers, the aquatic insects of *Baetis* sp., *Epeorus* sp., *Centroptilum* sp. and *Pagastia* sp. are dominant in density, while *Epeorus* sp. and *Centroptilum* sp. are dominant in biomass. It could be seen that the species, density and biomass of aquatic insects were not only related to the wet season and dry season, but also greatly different in the main stream and tributaries of the small mountain river. Therefore, it was necessary to make further study on the correlation between different water habitat parameters, such as flow velocity, sediment type and the community structure characteristics of aquatic insects.

Table 1. Density (ind./m^2) and biomass (g/m^2) of dominant species in the study river

Taxa	Dry season		Wet season	
	Density (%)	Biomass (%)	Density (%)	Biomass (%)
Baetis sp.	0.4	1.9	10.5	5.9
Epeorus sp.	<0.1	0.6	14.1	15.6
Centroptilum sp.	0	0	19.4	39.3
Pagastia sp.	0	0	12.2	0.8
Hydrobaenus sp.	25.8	19.0	1.6	0.1
Orthocladius sp.	27.3	14.8	3.0	1.5
Polypedilum sp.	29.8	6.6	0.1	<0.1

Considering the wide variety of aquatic insects, different groups have different requirements for velocity. Therefore, we first have divided the flow velocity into different grades, according to the field investigation results. Then, according to the frequency distribution of flow velocity from different sampling points, the flow velocity types have been divided into three different intervals >1.2m/s, 1.2-0.3m/s and <0.3 m/s by taking the first 75% and the last 25%. As shown in Table 1, in the mountain streams section with high velocity, the species of Lepidoptera and Ephemeroptera have accounted for more than 60% of the total aquatic insects. Among aquatic insects, Diptera, Coleoptera and Hemiptera have accounted for about 70%. To some extent, it indicated that Diptera, Coleoptera and Hemiptera had prefered to live in low velocity water environment..

Table 2. Proportion of aquatic insects species under different flow velocity

Taxa of aquatic insects	Velocity of flow (m/s)		
	>0.2m/s	0.3-1.2m/s	<0.3m/s
Diptera	33.1%	26.1%	43.3%
Lepidoptera	18.8%	18.8%	23.2%
Ephemeroptera	27.8%	27.8%	2.65%
Trichoptera	12.1%	15.1%	6.00%
Coleoptera	5.4%	8.4%	/
Hemiptera	2.8%	3.8%	25.1%

In the studied river reach in the wet season, the proportion of six orders of aquatic insects, including Diptera, Lepidoptera, Ephemeroptera, Trichoptera, Coleoptera and Hemiptera among five types of sediment were analysed. The statistical results showed that, compared with the dry season, the proportion of various categories of aquatic insects was similar in the wet season. The aquatic insetcs of Diptera accounts for a higher proportion in all types, especially in the large granular sediment and organic matter. Hemiptera aquatic insects are distributed in a high proportion in silt and organic sediment (Table 3.3). This results showed that the species distribution of aquatic insects is closely related to the sediment types of rivers in mountainous areas in the wet season and dry season in this study.

Table 3. Proportion of aquatic insects species in different sediment types in wet season

Taxa of aquatic insects	Different types of sediments			
	Large	Medium	sludge	organic matter
Diptera	38.1%	32.1%	/	49.0%
Lepidoptera	5.8%	7.8%	/	/
Ephemeroptera	37.8%	30.8%	/	/
Trichoptera	16.1%	19.1%	/	/
Coleoptera	1.4%	8.3%	/	27.0%
Hemiptera	0.8%	1.9%	69.0%	24.0%

4. Research prospects and suggestions

In the future, it is suggested to use physical model simulation combined with field investigation to study the community characteristics of aquatic insects under different flow velocity and sediment types in small rivers in mountainous areas. It is recommended to reveal the selection mechanism of aquatic insects on flow velocity and sediment, by constructing the coupling relationship between diversity index of aquatic insects and flow velocity and sediment, combined with the physiological structure of aquatic insects. It is prospected to provide scientific basis for the protection and restoration of aquatic habitats of small rivers in mountainous areas.

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