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Hydraulic Analysis on Microhabitat of Benthic Macroinvertebrates at Riparian Riffles

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Abstract**—**Hydraulic analysis on microhabitat of Benthic Macroinvertebrates was performed at riparian riffles of Hongcheon River and Gapyeong Stream. As for the representative species, *Ecdyonurus kibunensis*, *Paraleptophlebia cocorata*, *Chironomidae* sp. and *Psilotreta kisoensis iwata* were chosen. They showed hydraulically different habitat types by flow velocity and particle diameters of streambed materials. Habitat conditions of the swimmers were determined mainly by the flow velocity rather than by flow depth or by riverbed materials. Burrowers prefer sand and silt, and inhabited at the riverbed. Sprawlers prefer cobble or boulder and inhabited for velocity of 0.05-0.15 m/s. Clingers prefer pebble or cobble and inhabited for velocity of 0.06-0.15 m/s. They were found to be determined mainly by the flow velocity.

Keywords**—**Benthic macroinvertebrates, riffles, clinger, swimmer, burrower, sprawler.

I. Introduction

BENTHIC macroinvertebrates are animals that can be seen (macro) with the naked eye. They lack backbones (invertebrate) and live at least part of their lives in or on the bottom (benthos) of a body of water. Macroinvertebrates are retained by mesh sizes greater than or equal to 200 to 500 micrometers. They are widely used as the indicator organism to monitor the water quality and the environmental change of the stream ecosystem, since they have clearly different colony structure of specified species by the difference of stream environments [1]-[3].

Benthic Macroinvertebrates cover the 80% of the aquatic insects, and also include crustaceans, arthropods, mollusks, annelids and platyhelminthes [4]. Aquatic insects, especially, represent a choice group of organisms for use in biological monitoring programs [5].

The ecological study on Benthic Macroinvertebrates is mainly done by the population configuration in taxonomic group, habitat and life cycle aspect of the stream [6]-[8]. Gwak et al. [9] analyzed richness index and biomass variation affected by the precipitation and temperature difference at the polluted and clean streams. However, hydraulic studies on Benthic Macroinvertebrates are few. Lee et al. [10] have investigated the behavior of *Chironomus plumosus prasinus* against the flow in the artificial circulating channel through the hydraulic experiment, and compared it with the numerical model. But, they did not analyze flow characteristics and bed substrates of their habitat by the field investigations.

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Aquatic insects which cover the most part of the Benthic Macroinvertebrates have hydraulically different microhabitats even in the same streams, which are determined by hydraulic factors like flow depth, flow velocity and substrate. Depending on the habitat type of aquatic insects, they are classified into four groups of the sprawlers, the clingers, the burrowers and the swimmers [11].

This study analyzed the hydraulic characteristics of the microhabitats of the four groups of aquatic insects by measuring the flow velocity, flow depths, water temperature and diameters of the river bed materials by the field investigations.

II. Materials and Methods

As for the study area, the Hongcheon River where riffles are well developed are selected. Three sites at this river are near the downstream of Bangok Bridge shown in Fig. 1 and Table I. Three sites at the Gapyeong Stream were also included [12].

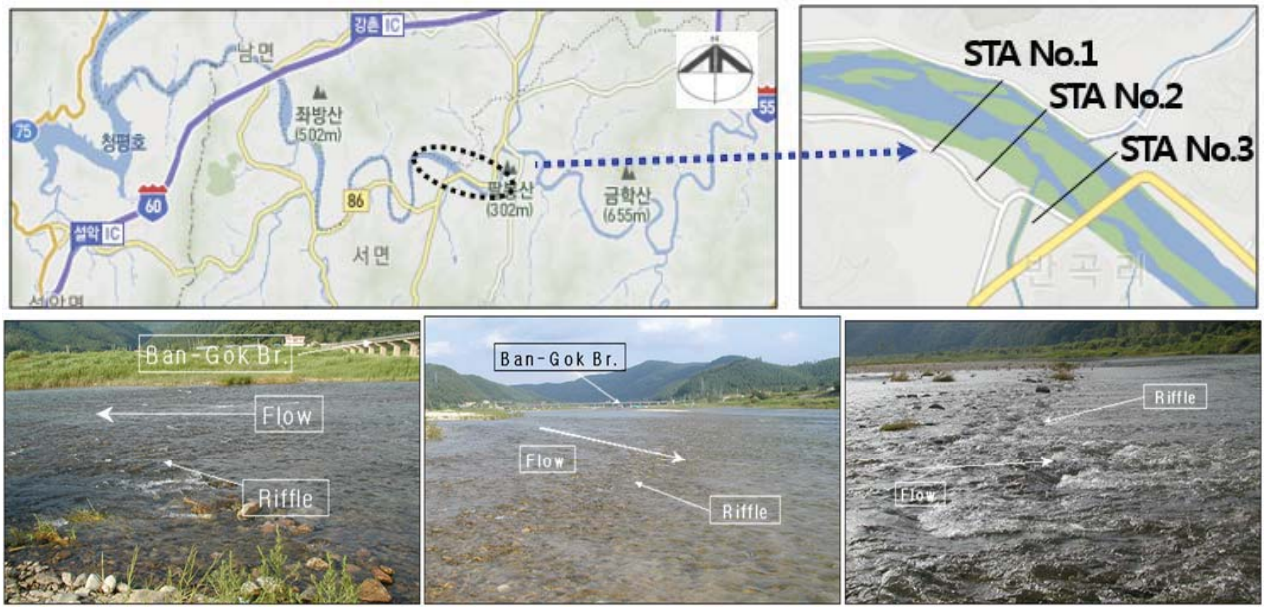
TABLE I
Location of Field Sites

River Basin	Study Area	Location
Hongcheon River	Site No.1	1.5km downstream of Bangok Bridge, Bangok-ri Seo-myeon Hongcheon
	Site No.2	1.1km downstream of Bangok Bridge, Bangok-ri Seo-myeon Hongcheon
	Site No.3	0.5km downstream of Bangok Bridge, Bangok-ri Seo-myeon Hongcheon

The sites are typical of granitic geology, and the habitat structures are characterized by turbulent riffles, small cascades, runs and pools. The river bed is composed largely of bedrock and boulders. The upstream part is steep and narrow, whereas the downstream part is relatively mild and wide. Although the stream runs through agricultural areas and small villages, water quality and ecological conditions are relatively well preserved.

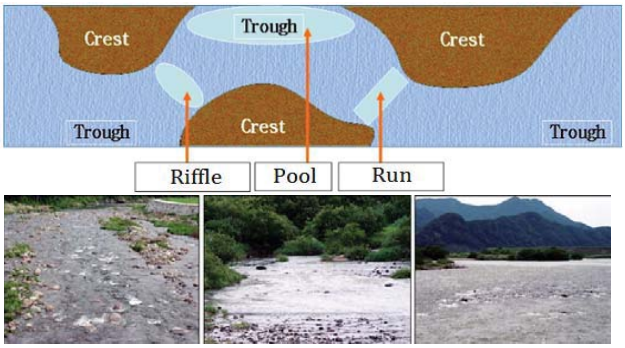
From the riffles formed in the alternating bars, the crests of the bars and troughs are formed. The riffles and pools cross each other. By the forming of the bars, erosion proceeds at the water attacking points and thus the pools are formed, which act as resting areas for aquatic creatures. At the upstream part of the pool, steep riffles are formed, and at the downstream part of the pools, runs of rather gentle flows are formed. Fig. 2 shows the formation of the riffles and pools [13].

The investigations were conducted from 2010 to 2013 (September 2010, March 2011, August 2011, April 2012, and Autumn 2013). The winter investigations were sometimes impossible due to freezing and the investigation during flood seasons were also impossible since the habitats are destroyed.



(a) STA No.1 (b) STA No.2 (c) STA No.3

Fig. 1 Location of study area



(a) Riffle (b) Pool (c) Run

Fig. 2 Formation of riffles and pools

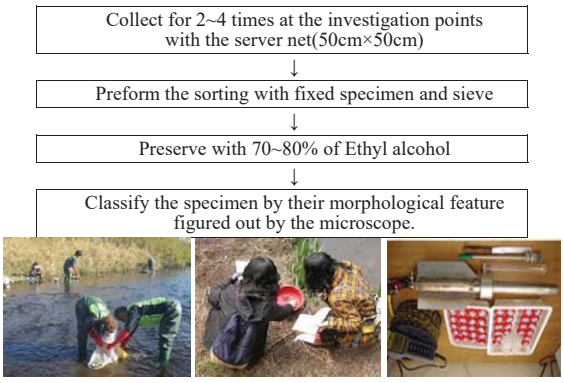


Fig. 3 Site sampling and analysis of Benthic Macroinvertebrates

For the hydraulic analyses, flow characteristics like the water temperature, depth, velocity and width were measured at 5-7 points per each site. DO and water temperatures were measured by portable YSI550 and the flow velocities were measured by acoustic flow tracker hydrometer which could be detected with ranges 0.01m/s to 3.00m/s. The measuring point of the flow velocity was 60% of the water depth from the river bed.

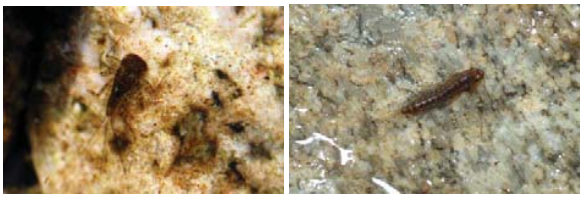
Benthic Macroinvertebrates were sampled quantitatively using a suber sampler (50 cm x 50 cm, mesh 0.2 mm thick). The samples were preserved with Kahle's solution and moved to the laboratory for sorting and identification. They were identified to the species level using microscope.

Site sampling and hydraulic investigation were conducted from downstream to upstream for avoiding flow disturbance. The procedures of site sampling and analysis are shown in Fig. 3.

III. Results

Among the four groups found at riparian riffles of field sites, the representative aquatic insects were the *Ecdyonurus kibunensis* as for clingers, *Paraleptophlebia cocorata* as for swimmers, *Chironomidae* sp. as for burrowers and the *Psilotreta kisoensis iwata* as for sprawlers. They are shown in Fig. 4.

The clingers which live at riffles with fast flow velocity, have morphological features like long and crooked claws, flat body and suctorial disc to resist the fast flow. The swimmers could swim like fish in the flowing waters for a while, and cling to the river bed or the aquatic plant. The burrowers live at the river beds of sands or silts, making small caves and hiding there. The sprawlers intake food creeping on the river bed and hide there.



(a) *Ecdyonurus kibunensis* (b) *Paraleptophlebia cocolata*

(c) *Chironomidae* ***spp*** (d) *Psilotreta* ***kisoensis iwata***

Fig. 4 Representative aquatic insects of four groups of Benthic Macroinvertebrates

The habitat region of four groups of Benthic Macro-invertebrates by flow velocity and flow depth is shown in Fig. 5.

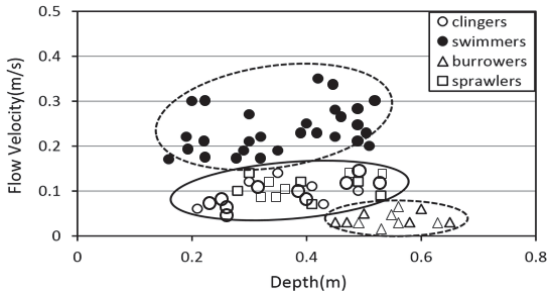


Fig. 5 Habitat region by flow velocity and flow depth

Clingers inhabit the region of the flow velocity of 0.06 m/s-0.15 m/s and the flow depth of 0.2 m-0.5 m. Swimmers were found in the habitats of the flow velocity of 0.15 m/s-0.36 m/s and the flow depth of 20%-80% from the river bed, and they cover far wider range of the flow velocity and the flow depth than the other groups. Burrowers inhabit on (or near) the river bed where the flow velocity is under 0.05 m/s. Sprawlers inhabit near the waterfront region of the small velocity of 0.05 m/s-0.15 m/s. Clingers and sprawlers live where the flow velocity and the flow depth are similar, and all the groups beside the burrowers lived in the similar depth. This is because the habitats of the Benthic Macroinvertebrates are determined by flow velocity rather than flow depth.

The habitat region of four groups by the flow cross section is shown in Fig. 6. They live mainly near the waterfront where the flow velocity is relatively low and where the foods like algae, plant pieces, humus and minerals are relatively abundant. Therefore, wider streams can have larger habitat area with possibility of low flow velocity and abundant food.

The habitat region by diameters of the river bed materials is shown in Fig. 7.

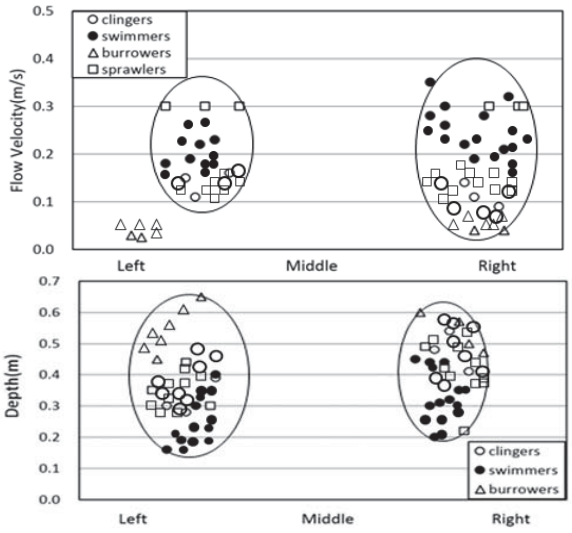


Fig. 6 Habitat region by flow cross section

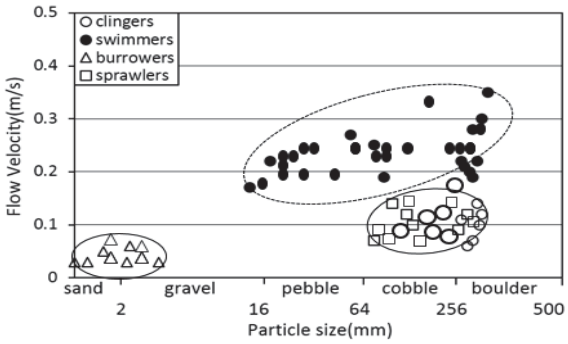


Fig. 7 Habitat region by particle size

The larger the diameter of the material is, the higher the side velocity and the lower the rear velocity are. Thus, the Benthic Macroinvertebrates live at the rear part rather than at the side of the river bed materials.

From the inhabitation situation, the burrowers live at sands or silts, whereas the clingers live at cobbles. The swimmers live in wider range of particle size of the bed materials and are not affected by its types. The sprawlers live at cobbles or boulders. The difference of habitat region by the river bed materials implies that they decrease the flow velocity and make it easy for the Benthic Macroinvertebrates to secure organic matters [14].

The habitat region by particle Reynolds number and flow Reynolds number with each groups are shown in Fig. 8. Here, Re_f is the flow Reynolds number and Re_p is the particle Reynolds number of the river bed material as shown in (1):

$$\mathrm{Re}_f = \frac{Uh}{v},\ \mathrm{Re}_p = \frac{UD}{v} \tag{1}$$

where U is the flow velocity, h is flow depth, v is coefficient of kinematic viscosity and D is the diameter of the river bed material.

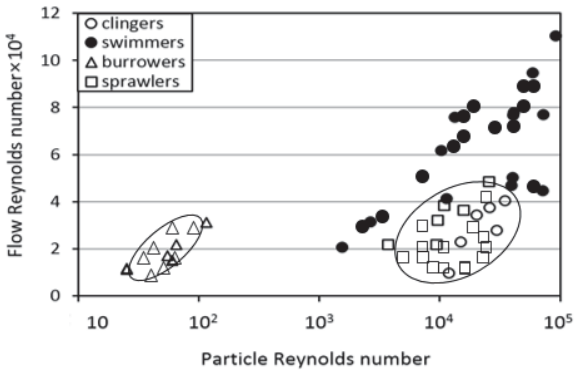


Fig. 8 Habitat region by particle and flow Reynolds number

The burrowers live where both Re_f and Re_p are small, the sprawlers and the clingers live in the range of small Re_f and large Re_p and the swimmers live at the wide range of Re_f and Re_p. This is because that the burrowers live where the water velocity and the river bed materials are small, the sprawlers and the clingers live where the water velocity and the river bed materials are big, and the swimmers live in the wide range of the flow velocity and the diameter of the river bed materials.

The habitat region by flow Froude number and Reynolds number are shown in figure. 9. Here, Fr is described by (2):

$$Fr = \frac{U}{\sqrt{gh}} \tag{2}$$

where g is the acceleration of gravity and the remaining variables were mentioned in (1).

Habitat region of Fig. 9 is more apparent than that of Fig. 8. The burrowers live where Re_f and Fr are very small, the sprawlers and clingers live where Re_f and Fr are small, and the swimmers live where Re_f and Fr are relatively large. They imply that the burrowers live where the water velocity is very small, the sprawlers and the clingers live where flow velocity is small, and the swimmers live where the flow velocity is large.

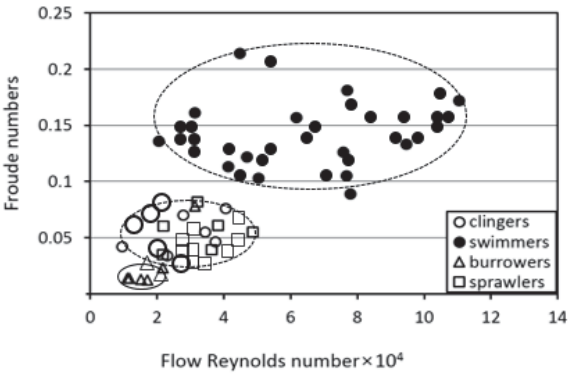


Fig. 9 Habitat region by flow Froude number and Reynolds number

The relationships of each habitat types with Manning's roughness coefficients are shown in Fig. 10. Here, Manning's roughness coefficients are calculated from the average velocity equation:

$$U = \frac{1}{n} R^{2/3} S_f^{1/2}, \quad N = \frac{R^{2/3} S_f^{1/2}}{U} \tag{3}$$

where U is the average flow velocity, R is hydraulic radius, S_f is the friction slope of the flow.

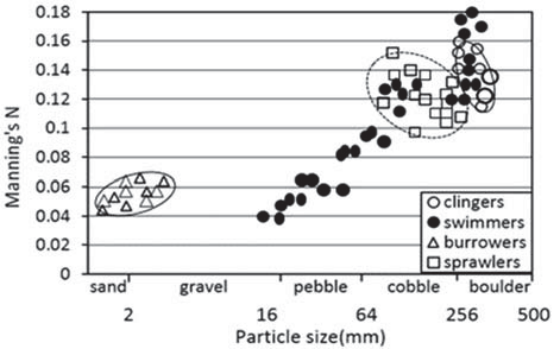


Fig. 10 Habitat region by Manning's N and particle size

The burrowers live in the area with the coefficient values of 0.041-0.062 and the sprawlers live in the area with the coefficient values of 0.105-0.150, the clingers live in the area with the coefficient values of 0.110-0.160, and the swimmers live in the area with the coefficient values of wide range. The reason of which is that the burrowers live at sands, the clingers live at cobbles, the sprawlers live at cobbles or boulders, and the swimmers live in wide range of the bed material. This shows the similar tendency with the analyses of Lee et al. [10] with sand's coefficient of 0.008- 0.250, cobble's coefficient of 0.015-0.327, and boulder's coefficient of 0.023-0.444. From these results, the Benthic Macroinvertebrates were found to live in the upstream or midstream part rather than in the downstream part of the streams. This implies that the high diversity of the bed structure ranging from gravels to boulders in the upstream or midstream part reduce the flow velocity and have higher resistant force than the downstream part, and thus provide good shelters. While the downstream part joins the tributaries and has increasing water amounts, which results the increased time of disturbance.

IV. Conclusions

Among the four groups of the Benthic Macroinvertebrates at the riparian riffles, the most representative species are *Ecdyonurus kibunensis*, *Paraleptophlebia cocora, Chironomidae* sp. and *Psilotreta kisoensis iwata*. Benthic Macroinvertebrates differ in species by the hydraulic properties such as the flow velocity, the flow depth and the materials of river bed. Clingers inhabit the region of the flow velocity of 0.06 m/s-0.15 m/s and the flow depth of 0.2 m-0.5 m. Swimmers were found in the habitats of the flow velocity of

0.15 m/s-0.36 m/s and the flow depth of 20%-80% from the river bed, and they cover far wider range of the flow velocity and the flow depth than the other groups. Burrowers inhabit where the flow velocity is under 0.05 m/s. Sprawlers inhabit near the waterfront region of the small velocity of 0.05 m/s-0.15 m/s and of the large depth. The burrowers live at sands or silts, whereas the clingers live at cobbles. The swimmers live in varied area and are not affected by the types of the river bed materials. The sprawlers live at cobbles or boulders. The burrowers live where both Re_f and Re_p are small, the sprawlers and the clingers live in the range of small Re_f and large Re_p, and the swimmers live at the wide range of Re_f and Re_p.

Acknowledgment

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