SPECIES COMPOSITION OF BENTHIC MACROINVERTEBRATE AND WATER EVALUATION AT THE JUNGCHEON STREAM IN KOREA

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ABSTRACT

This study was conducted to investigate water quality evaluation using benthic macroinvertebrates at a mountain torrential river (Jungcheon stream). From the four seasons survey, the identified benthic macroinvertebrates were 1,171 individuals belonged to 34 species, 30 families, 13 orders, 6 classes and 4 phyla. As the average results of four surveyed sites, the dominant species was *Culicini* sp. exhibited greatest individuals (219) and second species was *Asellidae* sp. The value of dominance index (DI) was a mean of 0.174. Total ecological score of benthic macroinvertebrate community (TESB) was varied from 64 (St. A) to 41 (St. D) with a mean of 51. Average ecological score of benthic macroinvertebrate community (AESB) was varied from 1.952 (St. D) to 2.783 (St. A) with a mean of 2.338. Benthic macroinvertebrate index (BMI)) was a mean of 39.756. The species diversity index (H') showed the highest as 2.614 at St. C and the lowest as 2.195 at St. A. Evenness indices (E2-E5) except E1 were different from each other, there were shown significant differences ($p>0.05$).

Keywords: Benthic macroinvertebrate index (BMI), dominance index (DI), Jungcheon stream.

INTRODUCTION

Water quality assessment can be done by several methods such as physical stream habitat conditions and chemical characteristics. In addition, biological methods can also be used for evaluation. It has been found that living organisms in the aquatic environment can be used as an indicator of the water quality (Rattanachan et al., 2016). Biomonitoring is recognized as one of the most valuable tools available in the arsenal of environmentalists. The organism groups most commonly used in routine biological monitoring and assessment programs. Biomonitoring is based on the straightforward premise that living organisms are the ultimate indicators of environmental quality (Mandaville, 2002).

Benthic macroinvertebrates are small animals living among the sediments and stones on the bottom of streams, rivers, and lakes. These communities are important links in the food web between producers (leaves, algae) and higher consumers such as fish and other aquatic animals, and are key indicators of biological integrity in streams, rivers and wetlands.

The focus of water quality evaluation shifted for much of the first half of the 20th century to the effects of chemical contaminants; rarely were connections between chemical criteria and ambient biotic condition documented (Abbasi & Abbasi, 2011). Over the past 30 years, bioassessment methods have progressed from the development of community health indices to initial attempts at using biological community composition to study the effects of particular stressors (Brazner & Beals, 1997; Karr & Yoder, 2004).

Benthic macroinvertebrate species are differentially sensitive to many biotic and abiotic factors in their environment. Consequently, macroinvertebrate community structure has commonly been used as an indicator of the condition of an aquatic system (Armitage et al., 1983; Rosenberg & Resh, 1993).
It is common practice among ecologists to complete the description of a community by one or two numbers expressing the "diversity" or the "evenness" of the community (Heip et al., 1998). This study analysed the qualitative and quantitative composition of the benthic aquatic communities on the Jungcheon stream in Korea. In adition, this study focuses on the application of saprobic extent and other ecological biodiversity methods for the assessment of river water quality.

METHODOLOGY

Surveyed regions

This study was carried out on the Jungcheon Stream (upper region: 35°296′851″N/128°234′679″E, low region: 35°297′285″N/128°259′047″E), located at Uiryeong-gun, Gyeongsangnam-do province in Korea (Fig. 1). Lowlands are usually no higher than 100m (328ft.), while uplands are somewhere around 130m (427ft.) to 160m (525ft.). The length of the stream is 3.1 km long and flows across the countryside. Flood plains of this river are usually very fertile agricultural areas and out sides of this river consist of a mosaic of agricultural fields.

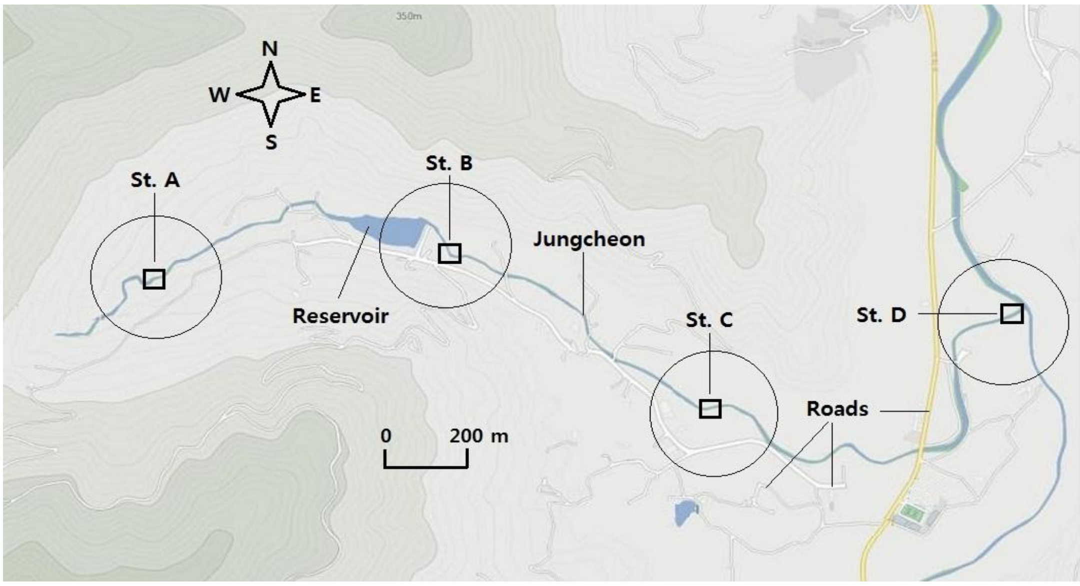

Fig. 1. Location of the study area and the three detailed internodes at the Jungchon Stream.

Sampling procedures

This protocol summarizes the USEPA (2003) Rapid Bioassessment Protocol III (RBP III) for benthic macroinvertebrates. A 100m reach that is representative of the characteristics of the stream should be selected. Whenever possible, the area was at least 100m upstream from any road or bridge crossing to minimize its effect on stream velocity, depth and overall habitat quality. Benthic macroinvertebrates are collected systematically from all available in-stream habitats by kicking the substrate or jabbing with a D-frame dip net and a Surber sampler (30 × 30 cm; net mesh size 1 mm). A total of 20 jabs (or kicks) are taken from all major habitat types in the reach, resulting in sampling approximately 3.1 ㎡ of habitat. Remove any large debris manually and use forceps or elutriation buckets to extract any organisms from the sample. All organisms identified from the same sample should be placed in a jar filled with 70% EtOH. An organism-based subsample (usually 100, 200, 300, or 500 organisms) is sorted in the laboratory and identified to the lowest practical taxon, generally genus or species.

Taxonomic identifications are checked against the most current and widely accepted list of names for a particular group to ensure their validity and use (Shin, 1993; Kwon, 1990; McCafferty 1981; Kawai 1985; Merrit & Cummins 1996; Yoon, 1995; Won, 2005).

Water evolution

Dominance index (DI) was calculated using the following formula:

DI=(N1+N2)/N

N1: Number of individuals in first dominant species

N2: Number of individuals in second dominant species

Beck-Tsuda's Biotic Index (BI) is based on the relative tolerances of macroinvertebrates to organic pollution, with field-sorting undertaken and identification to species level.

BI = 2xA + B

A: Number of intolerant species, B: Number of tolerant species.

Total ecological score of benthic macroinvertebrate community (TESB) was calculated by the method of Kong et al. (2018).

$$TESB = \sum_{i=1}^{s} Qi$$

s: Total number of species, Q_i: Environmental quality score of i species (= 1, 2, 3, 4, 5)
Average ecological score of benthic macroinvertebrate community (AESB) was calculated by the method of Kong et al. (2018)

$AESB = \sum_{i=1}^{s} Qi/S$

Table 1. Classification scheme of the environmental quality score of benthic macroinverterates according to the indicator table from NIER (2016)

Qi	Saprobic value	Saprobity	$BOD_{5(mg/L)}$
5	≤0.1	Xenosaprobic	≤1
4	>0.1 ~ 1.0	Oligosaprobic	>1 ~ 2
3	>1.0 ~ 2.0	β-mesosaprobic	>2 ~ 4
2	>2.0 ~ 3.0	α-mesosaprobic	>4 ~ 8
1	>3.0	Polysaprobic	>8

Table 2. The scheme of ESB accrding to the phase of environmental quality (NIER, 2002)

ESB	Environmental condition	Area determination	Water quality
81<	Very satisfactory	First priority water	I
61-80	Satisfactory	Priority protection water	I
41-60	Some satisfactory	Protection water	II
26-40	Some defectiveness	Improvement water	II
13-25	Defectiveness	Priority improvement water	III
<12	Very defectiveness	First priority improvement water	IV-V

An analysis was conducted of the Benthic Macroinvertebrate Index (BMI), a biometric assessment technique using the large scale animals that appeared at each station (Kong et al. 2012).

$$\mathrm{BMI} = \{4 - \frac{\sum_{n=1}^{n}(S_i H_i G_i)}{\sum_{n=1}^{n}(H_i G_i)}\}\mathrm{x}25$$

Si: Saprobic value of the species *i*, Hi : Relative abundance of the species *i*, Gi : Indicator weight value of the species *i*.

Table 3. Classification of benthic macroinvertebrates index (BMI) for the evaluation of river status (Kong et al., 2018)

Class	BMI	Status	
		Diversity	Disturbance sensitive tata
A	80≤-100	Least signs of alteration from undisturbed levels	Least signs of alteration from undisturbed levels
B	65≤-80	Slight alteration from undisturbed levels	Slight alteration from undisturbed levels
C	50≤-65	Significantly lower than alteration from undisturbed levels	Significantly lower than alteration from undisturbed levels
D	35≤-50	Very low species richness	Most of the sensitive taxa are absent
E	0-35	Several species are present or not	Sensitive taxa are absent. Insensitive taxa shows high abundance or not

The Shannon index is an information statistic index, which means it assumes all species are represented in a sample and that they are randomly sampled (Shannon & Weaver, 1998): the formula for calculating the Shannon diversity index (H') is

$H' = -\Sigma\, pi \ln pi$

*p*i is the proportion of important value of the *i*th species (*p*i = *n*i / N, *n*i is the important value index of *i*th species and N is the important value index of all the species).

$N1 = e^{H'}$

$N2 = 1/\lambda$

Where λ (Simpson's index) for a sample is defined as

$\lambda = \sum ni(ni-1)/ N(N-1)$

Species richness is the number of species of a particular taxon that characterizes a particular biological community, habitat or ecosystem type (Colwell, 2011). Richness estimation offers an alternative to rarefaction for comparing richness among incompletely inventoried communities.

The species richness of animals was calculated by using the method, Berger-Parker's index (BPI) and Margalef's indices (R1 and R2) of richness (Magurran, 1988). BPI = *N*max/N where *N*max is the number of individuals of the most abundant species, and N is the total of individuals of sample. Species evenness is a measure of biodiversity which quantifies how equal the community is numerically. Evenness indices (E1~E5) was calculated using important value index of species (Pielou, 1966; Hill, 1973).

Table 4. Classification of saprobity based on Shannon-Weaver's diversity, H' (Staub et al., 1970)

H'	Saprobity
0-1	polysaprobic
1-2	α-mesosaprobic
2-3	β-mesosaprobic
3-4.5	oligosaprobic

RESULTS

From the four seasons survey, the identified benthic macroinvertebrates were 1,171 individuals belonged to 34 species, 30 families, 13 orders, 6 classes and 4 phyla. Arthropoda exhibited greatest species diversity with 25 taxa identified, followed by Annelida (5 taxa). Platyhelminthes accounted for only one taxon for four seasons within the four studied areas. Mollusca exhibited four species. *Culicini* sp. exhibited greatest individuals (219) and second species was *Asellidae* sp. (140 individuals).

Table 5. Species composition for invertebrates in the studied areas

Phylum	St. A		St. B		St. C		St. D	
	Species	Individuals	Species	Individuals	Species	Individuals	Species	Individuals
Platyhelminthes	1	4	1	1	0		0	
Mollusca	3	16	4	15	3	10	2	5
Annelida	1	2	3	9	4	17	5	39
Arthropoda								
Malacostraca	2	19	2	36	1	44	1	60
Insecta	15	194	14	192	14	220	13	293
Total	22	235	24	253	22	291	21	397

The value of dominance index (DI) was varied from 0.163 (St. A) to 0.186 (St. D) with a mean of 0.174 (Fig. 2). DI was significantly different among the four regions.

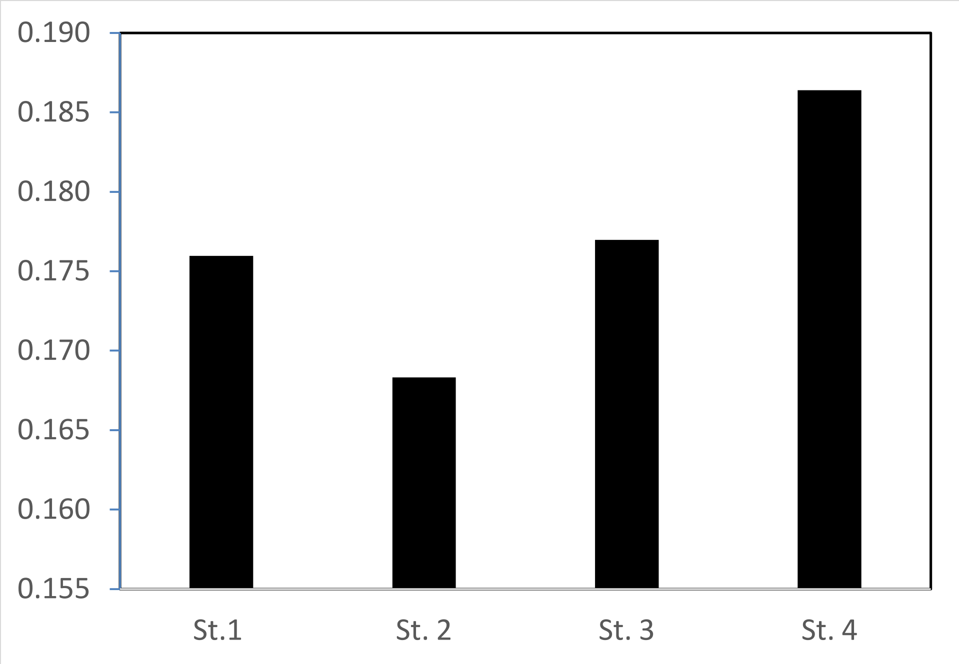

Fig. 2. Variability of the dominance indices (DI) of macroinvertebrate species in the benthos of the Jungcheon stream.

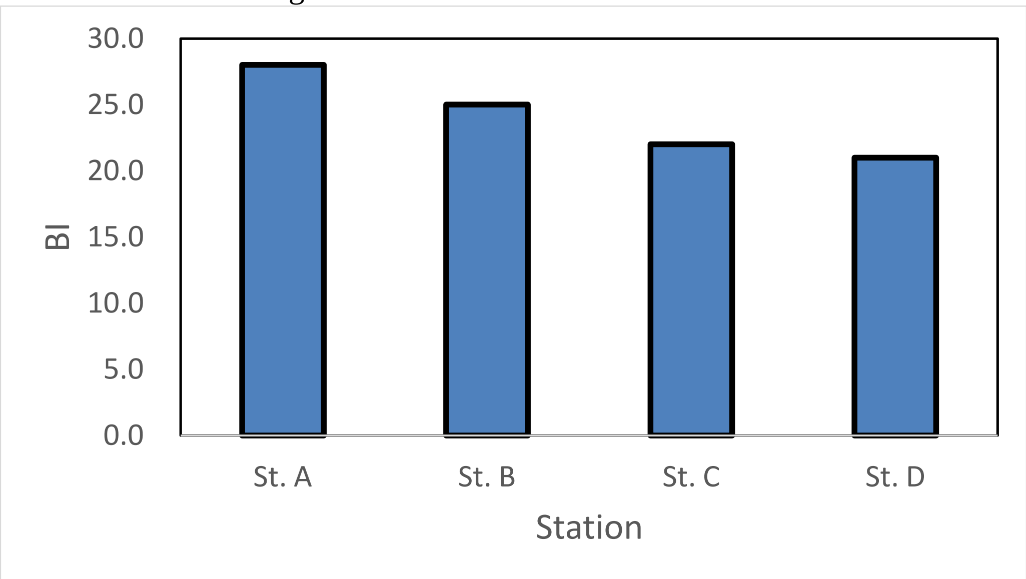

Fig. 3. Variability of the Beck-Tsuda's Biotic Index (BI) of macroinvertebrate species in the benthos of the Jungcheon stream.

Beck-Tsuda's Biotic Index (BI) was varied from 21 (St. D) to 28 (St. A) with a mean of 24 (Fig. 3). BI was not shown significantly different among the four regions.

Total ecological score of benthic macroinvertebrate community (TESB) was varied from 64 (St. A) to 41 (St. D) with a mean of 51 (Table 5). Average ecological score of benthic macroinvertebrate community (AESB) was varied from 1.952 (St. D) to 2.783 (St. A) with a mean of 2.338. Benthic macroinvertebrate index (BMI)) was varied from 28.275 (St. D) to 54.241 (St. A) with a mean of 39.756.

Table 5. Total ecological score of benthic macroinvertebrate community (TESB), average ecological score of benthic macroinvertebrate community (AESB), and benthic macroinvertebrate index (BMI) for the evaluation of river status (Kong et al., 2018)

Station	TESB	AESB	BMI
A	64	2.783	54.241
B	54	2.571	45.488
C	45	2.045	32.018
D	41	1.952	28.275
Mean	51	2.338	39.756

In order to assess macro-scale spatial variability of the animal community at the Jungcheon Stream, I analyzed distributions of species richness, diversity, and evenness of large taxonomic groups as well as four station compositions along a geographic distance (Table 6). Mean Shannon-Weaver index (H´) of diversity was varied from 2.195 (St. A) to 2.614 (St. C). H´ at the upper region (St. A) was lower than those of low region (St. D).

Berger-Parker's index (BPI) was varied from 0.179 (St. B) to 0.238 (St. A). N1 values were low at upper region and N2 values were high at upper region, meaning dominant species were different according to stations or seasons. Richness indices for animal taxa were also varied among the stations and seasons. Although richness indices (R1-R2) for four stations were different from each other, there were not shown significant differences ($p < 0.05$). Evenness indices (E2-E5) except E1 were different from each other, there were shown significant differences ($p>0.05$).

Table 6. Biological diversity index for invertebrates in the studied areas

Indices	St. A	St. B	St. C	St. D
No. of species	8	9	12	14
Richness				
BPI	0.238	0.179	0.203	0.222
R1	3.676	3.979	3.702	3.342
R2	1.382	1.449	1.290	1.054
Diversity				
H'	2.195	2.303	2.614	2.528
N1	8.983	10.003	13.658	12.534
N2	21.167	13.498	10.165	9.106
Evenness				
E1	0.721	0.734	0.846	0.830
E2	0.428	0.435	0.621	0.597
E3	0.399	0.409	0.603	0.577
E4	2.356	1.349	0.744	0.727
E5	2.526	1.388	0.724	0.703

DISCUSSION

The saprobic index and ESB for the evaluation of river status revealed that water quality at St. A was I (oligosaprobic) (Table 2). However, water quality at St. B, C, and D was II (β-mesosaprobic). Environmental status at St. A was also good (Table 2). Environmental status at St. B, C, and D was moderately good.

Classification of benthic macroinvertebrates index (BMI) for the evaluation of river status at St. A was significantly lower than alteration from undisturbed levels (Table 3). The evaluation of river status at St. B was most of the sensitive taxa are absent. The evaluation of river status at St. C and D was polysaprobic. Namely, sensitive taxa were absent and insensitive taxa showed high abundance or not.

Classification of saprobity based on Shannon-Weaver's diversity (H') was β-mesosaprobic at all stations (Table 4).

Two years ago, previous studies in this areareveraled species diversity including H' and species richness were not bad (Huh, 2017). Changes in water quality in a short time can affect invertebrates.

These spatial and temporal distributions suggest that benthic species have different preferences for particular ranges of temperature, pH, current velocity, and types of substrata. Colonization studies of streams and rivers also suggest that there are important differences in preferred use of microhabitats (Milner 1987). These differences in the ability of species to disperse to and live in certain microhabitats become especially important after major disturbances, when species abundances and community structure may shift.

The aquatic community in rivers responds to both the effects of pollution and changes in species composition. Therefore, species composition and the frequency of benthic macroinvertebrate communities are used as the basis for the characterisation and assessment of the ecological status of rivers. The BMI index can be expressed by subdividing the water quality. This may explain the better evaluation of BMI index that considers a weighting factor for each species, compared to DI and BI, a metrics based only presence/absence of *taxa*.

It is evident from studies of terrestrial or aquatic species that the number of species per se is not necessarily related to rates of ecosystem production (Chapin et al. 1997, Tilman et al. 1997). Instead, each species is adapted to function under variable conditions, with different species being of different relative importance to particular ecological processes (Covich et al, 1999). Changes in distributions and abundances of one species can result in disproportionate and unexpected responses by other species as they attempt to compensate functionally for changes in the associated species (Frost et al. 1995, Naeem 1998).

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