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Evaluation of Water Quality by Benthic Macroinvertebrate at the Jukjeon Stream in Korea

Man Kyu Huh and Hak Young Lee

ABSTRACT

This work was studied to investigate the water quality of the Jukjeon stream in Korea based on benthic macroinvertebrates. Several ecological score of benthic macroinvertebrate community were used in the estimation of stream from each of the three stations of the sub-watersheds. During the study periods, the results showed a total of 619 individual benthic macroinvertebrates were collected, including 23 families and 44 species. The first dominant species was *Culicini* sp. and second was *Baetis fuscatus*. Ecological score of benthic macroinvertebrate community (ESB) was varied from 61 (St. D) to 71 (St. A) with a mean of 66.5. Water quality at the Jukjeon Stream was grade I. The values of benthic macroinvertebrate index (BMI) at St. A and St. B were 60.4 and 53.4, respectively. Water quality at the two stations was grade C (moderate) on the based BMI. The values of BMI at St. C and St. D were 45.5 and 39.6, respectively. Water quality at the two stations was grade D (bad). The Shannon diversity index (H') of diversity was varied from 3.76 (St. A) to 4.18 (St. B) with a mean of 4.05. The rank percentages of species based on individual abundance (RI) were 4.84 (St. A), 5.66 (St. B), 6.31 (St. C), and 5.97 (St. D). Evenness indices (J) were varied from 0.79 (St. C) to 0.84 (St. B). The values of EPT (Ephemeroptera, Plecoptera and Tricoptera) at St. A, St. B, St. C, and St. D were 0.56, 0.48, 0.29, and 0.17 with a mean of 0.37, respectively. The EPT group accounted for 37% of the total species and 53% of the total individuals. The diversity and richness indices were lower in St. A than in the other stations. In this study, rapid assessment of water quality by macroinvertebrate indicators involves effort and reduced cost in natural stream evaluation.

Keywords: Benthic Macroinvertebrate Index (BMI), Ecological Score of Benthic Macroinvertebrate Community (ESB), Jukjeon Stream.

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I. Introduction

Fresh water in upon region or mountains is an important natural resource. Stream ecosystem health depends on macroinvertebrate communities [1]. The assessment of river water quality relies merely on physical and chemical (i.e., physicochemical) properties. In some cases, the concentration of microscopic algae and quantities of pesticides, herbicides, heavy metals, and other contaminants may also be measured to determine water quality. To estimate water quality is not simply thing because water quality and habitat conditions change. Although chemical parameters provide snap shots of the condition of a water-body, chemical analysis has limited items that can be detected and volatile chemicals produce different results depending on the timing of the irradiation. Thus there do not reflect the correct information of health of a stream [2]. It is necessary to estimate the water quality over time [3]. Early age, the saprobic index based on plankton against water pollution applied biological methods [4]. The analyses of plankton community in the small stream dependent in on the concentration of the nutrients present. The species and diversity of plankton is largely dependent on chemical fertilizers and pesticides in agricultural areas. Thus, there are many limitations concerning the application of plankton community in the small stream.

Benthic macroinvertebrate indicators are helpful tools for the assessment of water quality because they are less mobile and have a wide range of responses overall environmental stress of aquatic ecosystem [5]. Within the last decades after at the end of 80s, the numbers of macroinvertebrate analyses have used as biological monitoring of flowing water ecosystems such as streams and still waters such as lakes [6]-[8].

Various biological indices of benthic macroinvertebrates were developed for each micro habitat to assign water quality decision and they could reflect the cumulative effects of present and past conditions [9].

Many biotic indices are based on numerical expressions combining a quantitative measure of species diversity and

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provided an extensive and insightful information of the reference conditions and water quality assessment [4].

Many diversity indices have been applied on environment estimates including water quality in rivers [10]. Ecologists are primary interested in monitoring changes and the rate of quantified change in biological diversity within a region through time [11].

This study area is located at the Jukjeon stream which is located at Uiryeong-gun, Gyeongsangnam-do province in Korea. The stream is started at the mountains and the length of the stream is 4.2 km long. Both resevoirs are located at the upper regions. Originally, this area is a typical agricultural fields. Fortunately, this area has no industrial sources of pollutions except for farmers.

In this study we studied water saprobic extent and other ecological biodiversity indices at spatial and temporal scales of benthic macroinvertebrate community on the Jukjeon Stream in Korea.

II. Math

A. Surveyed Regions

This study area is located at the Jukjeon stream (upper region: 35˚22′50″N, 128˚17′52E, low region: 35˚22′01″N, 128˚19′39E which is located at Uiryeong-gun, Gyeongsangnam-do in Korea (Fig. 1). Lowlands are usually no higher than 100m (328ft.), while uplands are somewhere around 120m (393.7ft.). Two small streams flow into the middle of the Jukjeon stream in the northeast and southwest.

B. Sample Procedure

The aquatic macroinvertebrates were collected at four sampling locations (Fig. 1). A 10 × 10 m quadrate is representative which the characteristics of the stream should be selected. Sample procedures for benthic macroinvertebrates were conducted on the USEPA Rapid Bioassessment Protocol III (RBP III) [12].

Dip-net (> 0.5-meter-wide) and surber-on-a-stick (30 × 30 cm; net mesh size 1 mm) were used to sample benthic macroinvertebrates. The nylon bag and sieve bucket are freely floating immediately downstream of the net frame. Prior to sorting and identification organisms from the same sample sieved and removed debris. The organism preserved in a jar filled with 70% ethanol solution. An organism-based subsample were identified using only a dissecting microscope to the lowest practical taxonomic level (species or variety) and some mayfly structures must be mounted on glass slides and identified with a compound microscope.

C. Identification of Organism

The identification of benthic macroinvertebrates was based on morphology and taxonomic books such as most general accepted list of scientific names [13],[14]. Under most conditions a bio-classification for a stream station is generated following the collection of a benthic macroinvertebrates [15]-[17].

D. Evaluated Indices

The number of benthic macroinvertebrates was calculated as individuals per square meter.

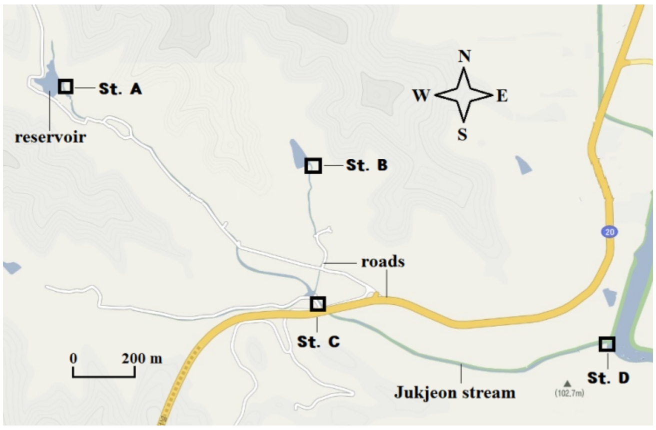

Fig. 1. The four stations (St. A – D) for macroinvertebrate sampling at Jukjeon Stream in Korea.

Several ecological indices are currently being used for a nationwide assessment of stream ecosystem that is supervised by the Ministry of Environment (Korea). A uniformity index and small diversity indicates a high dominance of a species, Dominance index (DI) formula is given in (1).

$$DI = (N1 + N2)/N \quad (1)$$

N1: the number of individuals in first dominant species.
N2: the number of individuals in second dominant species.
Beck-Tsuda's Biotic Index (BI) has defined as a parameter of purification of water using (2) [18].

$$\mathrm{BI} = \sum(s \cdot h)/\sum h \quad (2)$$

where, h is the number of individuals and s is the index of purification.

The ecological score of benthic macroinvertebrate community (ESB) was calculated on the environmental score (Q) corresponding the tolerance value of Korean benthic macroinvertebrate species and the related biotic score [19].

Total ecological score of benthic macroinvertebrate community (TESB) was calculated by the method of Kong [20] as in (3).

$$TESB = \sum_{i=1}^{s} Qi \quad (3)$$

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 [20] as in (4).

$$AESB = \sum_{i=1}^{s} Qi/\mathrm{S} \quad (4)$$

An analysis was conducted of the Benthic Macroinvertebrate Index (BMI), a biometric assessment technique using the large-scale animals that appeared at each station [21] given in (5).

$$\mathrm{BMI} = \{4 - \frac{\sum_{n=1}^{n}(S_i H_i G_i)}{\sum_{n=1}^{n}(H_i G_i)}\}\mathrm{x}25 \quad (5)$$

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

Intolerant order category index (i.e. EPT species richness) of Lenat [8] was calculated given in (6).

$$EPT = (E + P + T)/A \quad (6)$$

EPT is the number of species in Ehemeroptera (E), in Plecoptera (P), in Trichoptera (T). A: Total number of species.

The Shannon index (H') is a way to measure the diversity of species in a community [22]: this index is calculated using (7).

$$H' = -\Sigma\, pi \ \mathrm{In}\, pi \quad (7)$$

where, pi: the proportion of entire community made up of the ith species and In: natural log.

Species richness is simply the number of species in a community [23]. The richness index (RI) is a parameter for the total number of the species in a community. RI was calculated using (8).

$$RI = \frac{\mathrm{Si}}{\mathrm{S}}\ x\ 100 \quad (8)$$

Species evenness is a measure of the relative abundances of species within a community. Evenness indices (J) were calculated using important value index of species [24]. J was calculated as in (9).

$$J = \frac{H`}{In(N)} \quad (9)$$

TABLE I: THE SCHEME OF ESB ACCORDING TO THE PHASE OF ENVIRONMENTAL QUALITY

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

TABLE II: CLASSIFICATION OF BENTHIC MACROINVERTEBRATES INDEX (BMI) FOR THE EVALUATION OF RIVER STATUS

Class	BMI	Diversity	Disturbance sensitive taxa
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

TABLE III: THE PERCENTAGE RANGE OF APPEARANCE RANKING OF MACROINVERTEBRATES AT THE RIVER OR STREAM

Ranking percentage	≤20%	≤40%	≤60	≤80%	80%>
Appearance	5	4	3	2	1

III. RESULTS

Although the Jukjeon Stream was not a long river, it was inhabited by many bentic macroinvertebrates. 44 species of macroinvertebrates lived in the stream with 4 phyla, 5 classes, 15 orders, 23 families, and 619 individuals. Arthropoda was largest phylum with 33 species identified, followed by Mollusca (6 species) and Annelida (4 species) for four seasons within the four studied areas. Only one species, *Dugesia japonica* of Platyhelminthes occurred at the St. A, St. B, and St. C. The species was not found in the lower region of the stream. St. D represented the most species (29) and St. B represented the least number of species (25) (Table IV). *Culicini* sp. exhibited greatest individuals (109) and second species was *Baetis fuscatus* (54 individuals).

TABLE IV: SPECIES COMPOSITION FOR INVERTEBRATES AT THE JUKJEON STREAM

Phylum	St. A	St. B	St. C	St. D
Platyhelminthes	1	1	1	1
Mollusca	3	5	4	5
Annelida	1	0	3	4
Arthropoda	22	19	20	19
Total	27	25	28	29

The value of dominance index (DI) was varied from 0.26 (St. B) to 0.42 (St. A) with a mean of 0.33 (Fig. 2). DI was significantly different among the four regions.

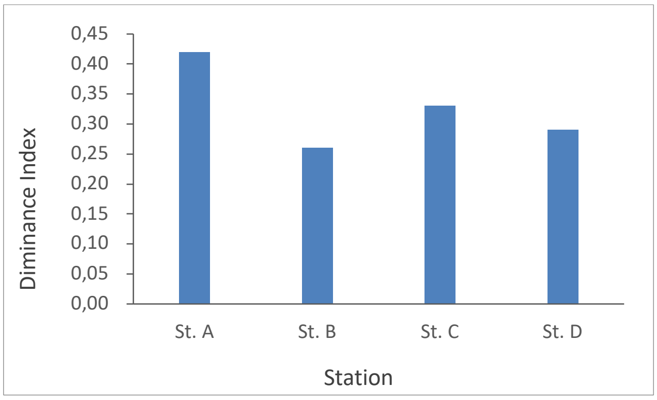

Fig. 2. The dominance index (DI) of macroinvertebrate sampling at the Jukjeon Stream.

Ecological score of benthic macroinvertebrate community (ESB) was varied from 0.61 (St. D) to 0.71 (St. A) with a mean of 66.5 (Table V). Water quality at the Jukjeon Stream was grade I.

Total ecological score of benthic macroinvertebrate community (TESB) at St. A was 76. Those of St. B, St. C, and St. D were 79, 75, and 81, respectively (Table V). The value of average ecological score of benthic macroinvertebrate community (AESB) was 3.62. Those of St. A, St. B, St. C, and St. D were 3.46, 3.44, 2.89, and 2.70, respectively.

TABLE V: ECOLOGICAL SCORE OF ESB, TESB, AESB AND WATER QUALITY AT THE JUKJEON STREAM

Station	ESB	TESB	AESB	Water quality
St. A	71	76	3.455	I
St. B	69	79	3.435	I
St. C	65	75	2.886	I
St. D	61	81	2.701	I

The values of benthic macroinvertebrate index (BMI) at St. A and St. B were 60.4 and 53.4, respectively (Table VI). Water quality at the two stations was grade C (moderate). The values of BMI at St. C and St. D were 45.5 and 39.6, respectively. Water quality at the two stations was grade D (bad).

TABLE VI: BENTIC MACROINVERTEBRATE INDEX (BMI) AND WATER QUALITY AT THE JUKJEON STREAM

	St. A	St. B	St. C	St. D
BMI	60.4	53.4	45.5	39.6
Water quality	C	C	D	D

H´ of diversity was varied from 3.76 (St. A) to 4.18 (St. B) with a mean of 4.05 (Table VII). The rank percentages of species based on individual abundance (RI) were 4.84 (St. A), 5.66 (St. B), 6.31 (St. C), and 5.97 (St. D). Evenness indices (J) varied from 0.79 (St. C) to 0.84 (St. B).

TABLE VII: ECOLOGICAL DIVERSITY AT THE JUKJEON STREAM

Diversity	St. A	St. B	St. C	St. D
H`	3.76	4.18	4.10	4.16
RI	4.84	5.66	6.31	5.97
J	0.80	0.84	0.79	0.82

At the species level, the values of EPT (Ephemeroptera, Plecoptera and Tricoptera) at St. A, St. B, St. C, and St. D were 0.56, 0.48, 0.29, and 0.17 with a mean of 0.37, respectively (Table VIII). The EPT group accounted for 37% of the total species and 53% of the total individuals. The values of EPT at the individual level were varied 0.17 (St. D) to 0.70 (St. A). The point-by-point difference in EPT at the individual level was greater than at the species level.

TABLE VIII: INTOLERANT ORDER CATEGORY INDEX (EPT) OF BENTHIC MACROINVERTEBRATES AT THE JUKJEON STREAM

Station	Level	
	Species	Individuals
St. A	0.56	0.70
St. B	0.48	0.62
St. C	0.29	0.38
St. D	0.17	0.17

Classification of appearance according to the percentage range of appearance ranking of macroinvertebrates (Table IX). St. D had the highest appearance ranking score among the four stations.

TABLE IX: CLASSIFICATION OF APPEARANCE ACCORDING TO THE PERCENTAGE RANGE OF APPEARANCE RANKING OF MACROINVERTEBRATES AT THE JUKJEON STREAM

Ranking percentage	St. A	St. B	St. C	St. D
Total	72	72	92	98

IV. DISCUSSION

The value of ESB for the evaluation of the Jukjeon Stream status was higher at the downstream than upstream. It revealed that environmental condition of downstream (St. D) was estimated 'Satisfactory' according to the phase of environmental quality (Table V) and water quality at St. A was 'I'. However, water quality at St. D was priority protection water. Although the upstream is slightly better at water quality assessment than the downstream, the water quality of this stream is deemed to be poor based on BMI standards. Disturbance-sensitive taxa was most of the sensitive taxa are absent (Table V). This is related to BMI characteristics. The final score is obtained by dividing the sum of the score obtained for each taxon by all number of taxa [25].

The spatial distribution of benthic macroinvertebrates is shown by diverse environmental factors such as river width, topography, and anthropogenic effects, which are critical for their establishment in natural ecosystems. The spatial heterogeneity is generally related to the degree of a population growth. A population showed spatial heterogeneity. The downstream of the Jukjeon Stream has a larger population than the upstream. They used environmental resources. It results in the variance seen in the spatial distribution of water quality and human activities. The reason why the water quality is better in the upper region than the lower region is that there is a reservoir in the upper region and there is less access by people. In the downstream area, as shown in Fig. 1, oil outflows and dust generation due to automobiles on the road are adding pollution to sewage in addition to daily sewage.

Human impact is changing the availability of freshwater and habitat of benthic macroinvertebrate fauna [26]. The downstream area has a wide river width, so there is enough habitat for living things, there was decreased the number of species and biological species diversity at low region in many small Korean streams [27]. Many freshwater ecosystems, streams and rivers are industrialized and urbanized. These regions threatened invertebrates that live only clean areas [28].

Benthic macroinvertebrates are sub-consumers that connect producers and upper consumers in the food chain of the aquatic ecosystem and are sensitive to environmental changes and have excellent indicators, so they are used as indicator organisms for water quality evaluation [29]-[30].

V. CONCLUSION

The benthic macroinvertebrate fauna of the investigated the Jukjeon Stream are different at four stations. Culicini sp. was the dominant species at the Jukjeon Stream. Some species were sensitive to the environmental conditions and they were absent at downstream regions. Macroinvertebrates are suitable indicators of the water condition of a small stream as they are found in almost all freshwater environments.

CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest.

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