# SPECIES COMPOSITION OF BENTHIC MACROINVERTEBRATE AND WATER EVALUATION AT BACKCHEON RIVER IN KOREA

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## ABSTRACT

This investigation on the structure of the benthic macroinvertebrate communities was conducted on Backcheon river South Korea to assess the cumulative effects of water quality on the aquatic biota. From the four seasons survey, a total of 24 macrobenthic species belonging to four phyla, five classes and eleven orders were identified. Dominant species was *Culicini* sp. which exhibited greatest individuals (141) and second dominant species was *Chironominaee* sp. (88 individuals). The value of dominance index (DI) was varied from 0.124 (St. A) to 0.278 (St. C) with a mean of 0.226. Total ecological score of benthic macroinvertebrate community (TESB) was varied from 21 (St. D) to 41 (St. A) with a mean of 29.3. Benthic macroinvertebrate index (BMI) was varied from 18.916 (St. D) to 46.607 (St. A) with a mean of 29.462. The value of geometric density was 1.784. Mean Shannon-Weaver index (H′) of diversity was varied from 2.024 (St. D) to 2.745 (St. A). H′ at the upper region (St. A) was higher than those of low region (St. D).

**Keywords:** Backcheon river, benthic macroinvertebrate index (BMI), dominance index (DI), water quality.

## INTRODUCTION

Water is increasingly becoming a priority policy issue at the international level. Inflowing water quality is as important as water quantity. The prediction that a water quality-related problem will occur requires evaluation of the potential of the water to create soil conditions that may restrict its use or that may require the use of special management techniques to maintain acceptable yields. Irrigated agriculture is dependent on an adequate water supply of usable quality. Agriculture, which accounts for 70 percent of water abstractions worldwide, plays a major role in water pollution. Farms discharge large quantities of agrochemicals, organic matter, drug residues, sediments and saline drainage into water bodies.

Understanding the relationship between human activities water quality is helpful for identifying primary threats to water quality, and the relationships are meaningful for effective water quality management because they can be used to target critical land use areas and to institute relevant measures to minimize pollutant loadings (Abler et al., 2002; Ding et al., 2005). Human settlements, industries and agriculture are the major sources of water pollution. Lee et al. (2009) found urbanization, rather than agricultural land use, was a major factor in water quality degradation in South Korea.

There is a need to develop the global monitoring information system on water quality to provide the information needed for water management and to monitor progress against targets. Many countries do not have conducted adequate water quality monitoring programs due to not the high initial capital expenditure in setting up an environmental laboratory, but also to costs including equipment maintenance, consumables, staffing, and quality control (Robarts et al., 2008). Biological monitoring is an effective tool to assess the ecological quality of a watercourse. Chemical monitoring can also be very important to understand water quality, but it is expensive in terms of equipment and time and often offers only limited information. Furthermore, biological monitoring can give an indication of past as well as present conditions (Fenoglio1 et al., 2002). In developing multimetric indices using benthic macroinvertebrates in various stream environments worldwide, a great number of metrics have been studied and accordingly evaluated in streams (Kerans & Karr, 1994; Klemm et al.,2002; Whittier et al., 2007; Won et al., 2012).

Biological monitoring of aquatic ecosystem programs began to be used after the Saprobic System developed by Kolkwitz & Marsson (1908, 1909), which established the conceptual basis for biomonitoring methods (Baptista, 2007). Benthic macroinvertebrate applied as useful biological indicators aquatic ecosystem health. As water quality and habitat conditions change, the benthic macroinvertebrate community also changes. Many species among them are responsive to pollution and abrupt changes in their surroundings. Unlike fish and other vertebrates, benthic macroinvertebrates are less mobile and are unable or unlikely to escape the effects of sediment and other pollutants that diminish water quality. Benthic macroinvertebrates represent a diverse group of aquatic animals.

This study analyzed whether the qualitative and quantitative composition of the benthic aquatic communities was significant spatial-temporal differences in the structure of benthic communities between areas on Backcheon river in Korea or not. In addition, 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 Backcheon river, located at Yonghyeon-myeon province (upper region: 34°977′088″N/128°083′815″E, low region: 35°055′262″N/128°042′942″E), located at Sacheon-ci, Gyeongsangnam-do province in Korea (Fig. 1). Uplands are usually no higher than 250m. Flood plains of this river are usually very fertile agricultural areas and out sides of this river consist of a mosaic of agricultural fields.

### Sampling procedures

Four sites exposed to various anthropic impacts were examined along the river of Backcheon (Fig. 1). Benthic macroinvertebrate sampling followed USEPA (2003) Rapid Bioassessment Protocol III (RBP III) and was performed using a multi-habitat approach within each 100 m reach length. At each site, we sampled a total of four transects from each location. At each transect, the macroinvertebrates were collected for four sweeps using a D-frame dip net (0.3 m wide and length, 500 μm mesh). 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. All samples were combined into a single sample and preserved in the field with 70% ethanol. In the laboratory, specimens were rinsed in 500 μm mesh sieves and large organic materials were removed. All organisms from the sorted sample were identified to the lowest possible taxonomic taxon based on accepted list of names for a particular group to ensure their validity and use (Shin, 1993; McCafferty 1981; Kawai 1985; Merrit & Cummins 1996; Yoon, 1995; Won, 2005). Those specimens were assigned to operational taxonomic units (OTUs).

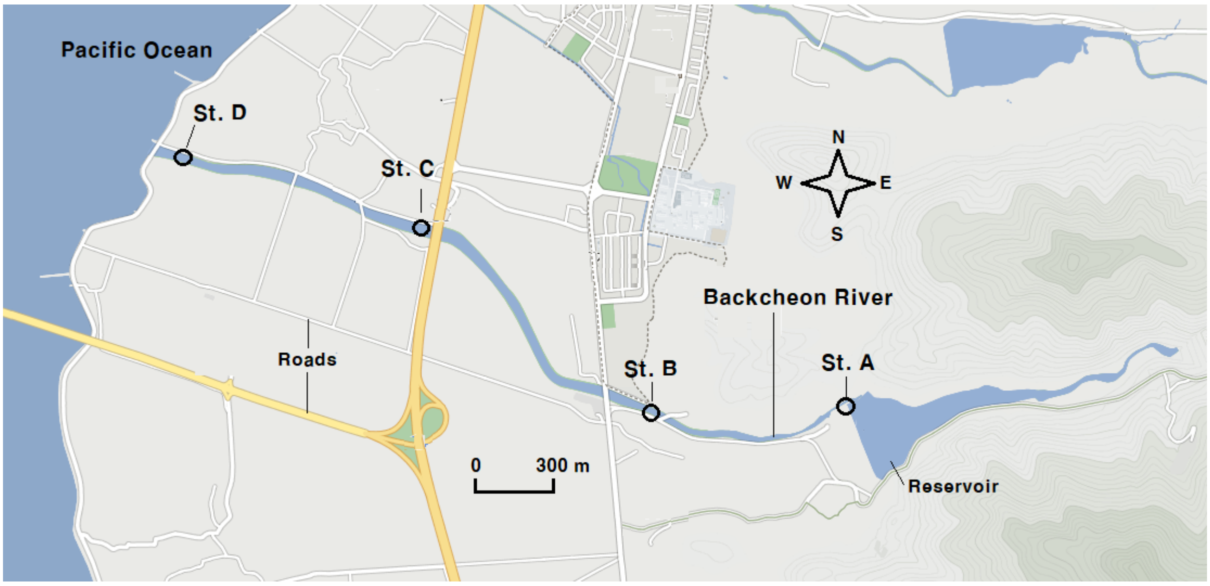


Fig. 1. Map showing locations of sampling sites along the Backcheon river.

**Water evaluation**

Many indices only account for categorical diversity between subjects or entities.

Dominance index (DI) was calculated using the formula, DI=(N1+N2)/N, where N1 is number of individuals in first dominant species and N2 is number of individuals in second dominant species. Another community index, Beck-Tsuda's Biotic Index (BI) (Tsuda, 1964), is based on weighted community indices. Total ecological score of benthic macroinvertebrate community (TESB) was calculated by the method of Kong et al. (2018). Average ecological score of benthic macroinvertebrate community (AESB) was calculated by the method of Kong et al. (2018)

**Table 1. Classification scheme of the environmental quality score of benthic macroinvertebrates 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 according 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).

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

| Class | BMI | Status | |
|---|---|---|---|
| | | 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 |

Arithmetic mean of relative abundance indices. The species-specific densities (Dij) are scaled by dividing the time series for each species by its estimated density at the initial time point (Buckland et al., 2005).

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

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

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. Representative benthic macroinvertebrate taxa in Korean streams according to saprobic value based on Shannon - Wiener's species diversity index (H') (Bae and Lee, 2001)**

| H' | Saprobitic categories | Representative benthic macroinvertebrate taxa |
|---|---|---|
| 0-0.9 | Polysaprobic | Tubificidae |
| 1-1.9 | α-mesosaprobic | *Chironomus yoshimatsui* - group |
| 2-2.9 | β-mesosaprobic | *Hydropsyche kozhantschikovi*, *Uracanthella rufa*, *Epeorus latifolium* |
| 3-4.5 | Oligosaprobic | *Drunella*, Plecoptera, *Rhyacophila* |

## RESULTS

From the four seasons survey, a total of 24 macrobenthic species belonging to four phyla, five classes and eleven orders were identified (Table 5). One Fifteen species of benthic invertebrates belonging to Platyhelminthes, four species under Mollusca, four species under Annelida, and Fifteen species under Arthropoda were found. Dominant species was *Culicini* sp. which exhibited greatest individuals (141) and second dominant species was *Chironominaee* sp. (88 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 | 2 | | | | | | |
| Mollusca | 4 | 13 | 3 | 10 | 1 | 4 | 1 | 3 |
| Annelida | 1 | 4 | 2 | 7 | 4 | 14 | 4 | 12 |
| Arthropoda | 9 | 39 | 8 | 73 | 9 | 105 | 8 | 87 |
| Total | 15 | 58 | 13 | 90 | 14 | 123 | 12 | 102 |

The value of dominance index (DI) was varied from 0.124 (St. A) to 0.278 (St. C) with a mean of 0.226 (Fig. 2). DI was significantly different among the four regions ($p > 0.05$).

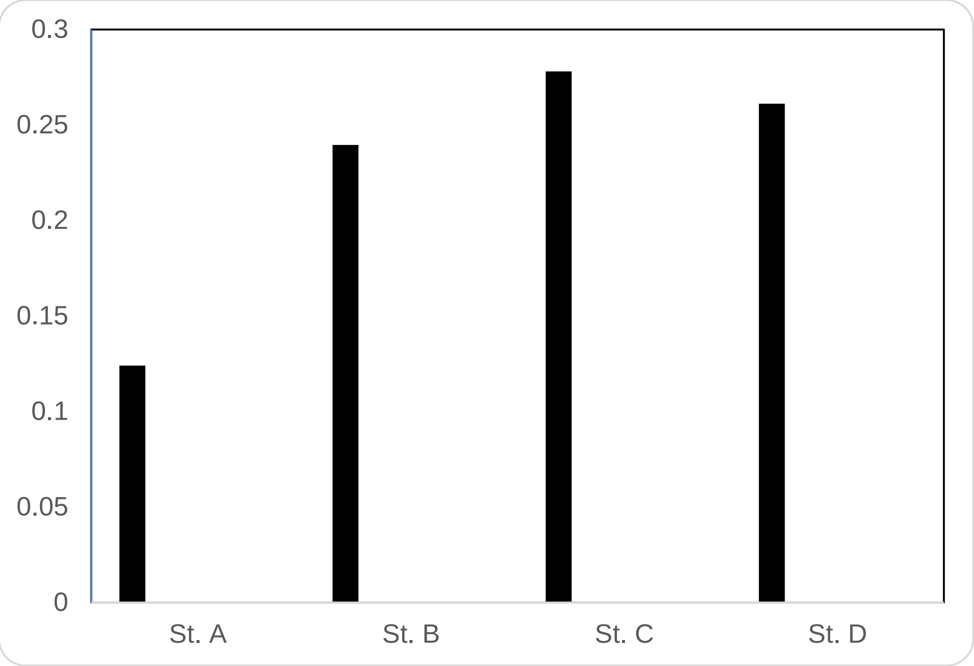


Fig. 2. Variability of the dominance indices (DI) of macroinvertebrate species in the benthos of Backcheon river.

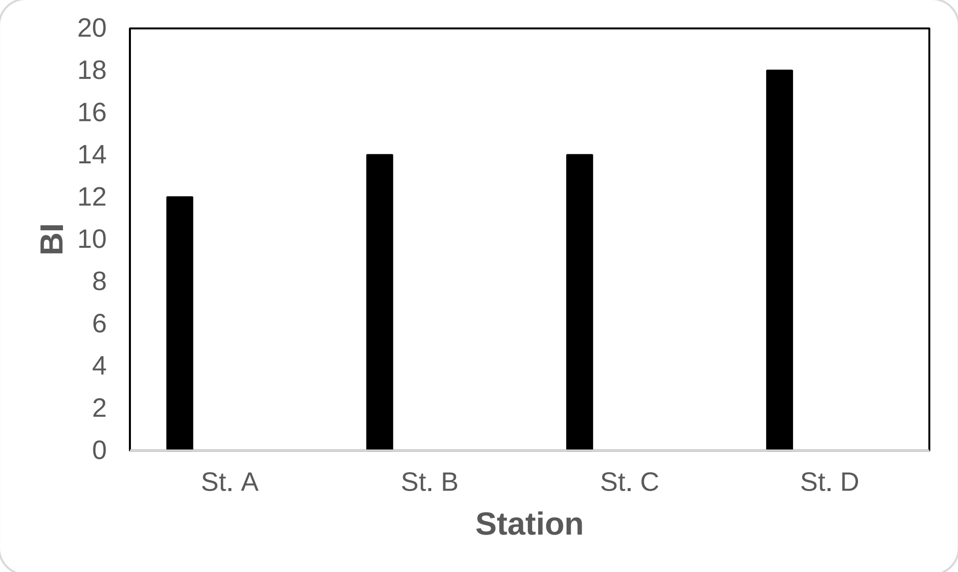


Fig. 3. Variability of the Beck-Tsuda's Biotic Index (BI) of macroinvertebrate species in the benthos of Backcheon river.

Beck-Tsuda's Biotic Index (BI) was varied from 12 (St. A) to 18 (St. D) with a mean of 14.5 (Fig. 3). BI was not shown significantly different among the four regions ($p < 0.05$).

Total ecological score of benthic macroinvertebrate community (TESB) was varied from 21 (St. D) to 41 (St. A) with a mean of 29.3 (Table 5). Average ecological score of benthic macroinvertebrate community (AESB) was varied from 1.750 (St. D) to 2.733 (St. A) with a mean of 2.143. Benthic macroinvertebrate index (BMI) was varied from 18.916 (St. D) to 46.607 (St. A) with a mean of 29.462.

**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 | 41 | 2.733 | 46.607 |
| B | 29 | 2.231 | 31.605 |
| C | 26 | 1.857 | 20.720 |
| D | 21 | 1.750 | 18.916 |
| Mean | 29.3 | 2.143 | 29.462 |

In this paper, the density of each species in the group and summing across species was shown in figure 4. The value of geometric density was varied from 0.763 (St. A) to 2.923 (St. D) with a mean of 1.783.

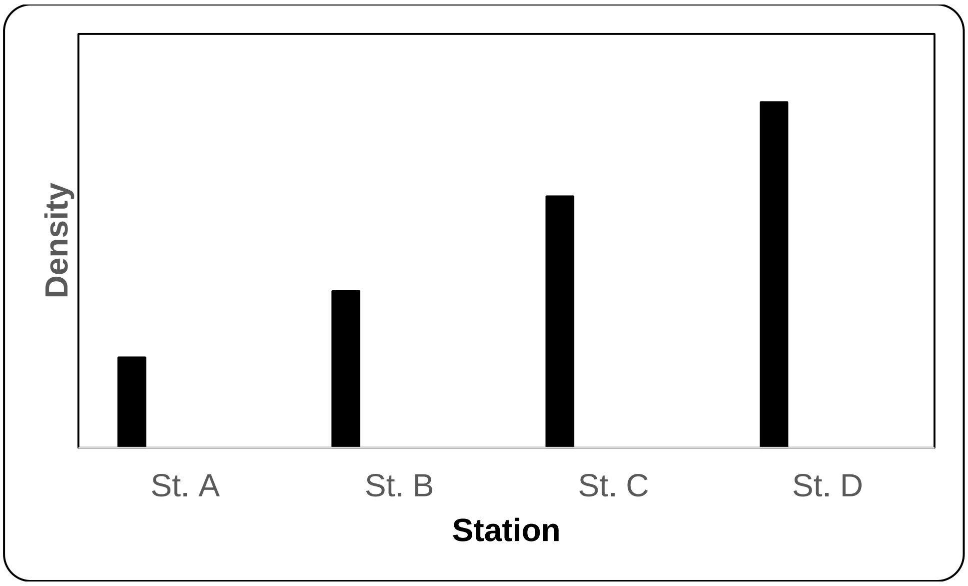


Fig. 4. The geometric mean of macroinvertebrate species at Backcheon river.

The density of each species in the group and summing across species was shown in figure 4. The value of geometric density was varied from 0.763 (St. A) to 2.923 (St. D) with a mean of 1.784.

In order to assess macro-scale spatial variability of the animal community at Backcheon river, 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 2.024 (St. D) to 2.745 (St. A). H´ at the upper region (St. A) was higher than those of low region (St. D).

Berger-Parker's index (BPI) was varied from 0.207 (St. A) to 0.444 (St. B). N1 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 E5 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 |
|---|---|---|---|---|
| Richness | | | | |
| BPI | 0.207 | 0.444 | 0.431 | 0.353 |
| R1 | 4.433 | 3.556 | 3.533 | 2.595 |
| R2 | 2.495 | 1.792 | 4.652 | 5.310 |
| Diversity | | | | |
| H' | 2.745 | 2.192 | 2.145 | 2.024 |
| N1 | 15.571 | 8.952 | 8.543 | 7.569 |
| N2 | 15.027 | 4.751 | 4.652 | 5.310 |
| Evenness | | | | |

| | | | | |
|---|---|---|---|---|
| E1 | 0.932 | 0.774 | 0.742 | 0.789 |
| E2 | 0.820 | 0.527 | 0.475 | 0.582 |
| E3 | 0.810 | 0.497 | 0.444 | 0.547 |
| E4 | 0.965 | 0.531 | 0.545 | 0.702 |
| E5 | 0.963 | 0.472 | 0.484 | 0.656 |

## DISCUSSION

Three years ago, previous studies in this area revealed species diversity including H' and species richness were not very bad although water quality is not good condition (Huh, 2017). The H´ values for vertebrates in this river were 2.500 (St. A), 2.5449 (St. B), 2.355 (St. C), and 2.234 (St. D). In this study, the H´ values were 2.745 (St. A), 2.192 (St. B), 2.145 (St. C), and 2.024 (St. D). Diversity has fallen in three regions except St. A compared to three years ago. Changes in water quality in a short time can affect invertebrates. Availability of Backcheon river water shrinking not only in quantitative terms, but also in qualitative terms because many river water systems have become increasing polluted with a wide variety of human, agricultural waters (Shikolmanov, 2000). In Africa and Asia, an estimated 85-90% of all fresh water used is for agriculture. While agriculture is not the only activity with the potential to affect fresh water negatively, it is a very important one. There may be surface runoff of pesticides, fertilizers and manure, or leaching of nitrogen into groundwater, the fate of which is discharge to surface water bodies. In agriculture, irrigation is used for the water from rivers discharged from the reservoir at upper regions (Fig. 1). In the winter, there is almost no rain, and the reservoir is not discharged, so the river becomes depleted temporary. So animals go into hibernation or dig into the soil. Biodiversity is reduced during this period.

The scheme of ESB for the evaluation of river status revealed that water quality at St. A was II (oligosaprobic) (Table 2). However, water quality at St. B St. C was II (β-mesosaprobic). water quality at St. D was III (α-mesosaprobic). Environmental status at St. A was some satisfactory (Table 2). Environmental status at St. B and St. C was some defectiveness. Environmental status at St. D was defectiveness.

Classification of benthic macroinvertebrates index (BMI) for disturbance sensitive taxa. St. A was most of the sensitive taxa were absent (Table 3). Sensitive taxa were absent at St. B, St. C, and St. D 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). This Total Biotic Score method (TBS method) has been modified into a simplified biotic index, which is widely used for South Korean streams these days (Bae and Lee, 2001). The TESB showed a sharp difference in upstream, middle, and downstream (Table 5). Nitrogen and phosphorus enter Middle and downstream of Backcheon river from the cultivated fields. These chemicals reduce the diversity of invertebrates and make them difficult to survive. Therefore, in the middle and the downstream, several values of water quality were lower than the upper stream.

## REFERENCES

Abler, D., Shortle, J., Carmichael, J., Horan, R. (2002) Climate change, agriculture, and water quality in the Chesapeake Bay region. *Climatic Change*, *55*, 339-59.

Bae, Y.J., & Lee, B.H. (2001). Human impacts on stream ecosystems and freshwater arthropods in Korea. *Korean Journal of Entomology, 31*, 63-76.

Baptista, D.F., Buss, D.F., Egler, M., Giovanelli, A., Silseira, M.P. & Nessimian, J.L. (2007) A multimetric index based on benthic macroinvertebrates for evaluation of Atlantic Forest streams at Rio de Janeiro State, Brazil. *Hydrobiologia, 575*, 83-94.

Buckland, S.T., Magurran, A.E. Green, R.E., & Fewster, R.M. (2005) Monitoring change in biodiversity through composite indices. *Philosophical Transactions of the Royal Society B, 360*, 243-54.

Ding, J., Jiang, Y., Fu, L., Liu, Q., Peng, Q., & Kang, M. (2015) Impacts of land use on surface water quality in a subtropical river basin: a case study of the Dongjiang river basin, Southeastern China. *Water, 7*, 4427-45.

Fenoglio, S., Badino, G., & Bona, F. (2002) Benthic macroinvertebrate communities as indicators of river environment quality: an experience in Nicaragua. *Revista de Biologia Tropical, 50*, 1125-31.

Hill, M.O. (1973) Diversity and evenness: a unifying notation and its consequences. *Ecology, 54*, 423-32.

Huh, M.K. (2016) Biological diversity of kingdom animalia at the Backcheon River in Sacheon-ci, Korea. *Journal of Scientific and Engineering Research, 3*, 78-84.

Kawai, T. (1985) *An illustrated book of aquatic insects of Japan*. Tokyo: Tokai Univ. Press.

Kerans, B.L., & Karr, J.R. (1994) A benthic index of biotic integrity (B-IBI) for rivers of the Tennessee valley. *Ecol. Appl. 4*, 768–85.

Klemm, D.J., Blocksom, K.A., Thoeny, W.T., Fulk, F.A., Herlihy, A.T., Kaufmann, P.R., & Cormier, S.M. (2002) Methods development and use of macroinvertebrates as indicators of ecological conditions for streams in the mid-Atlantic highlands region. *Environmental Monitoring and Assessment, 78*, 169–212.

Kolkwitz, R., & Marsson, M. (1908) Okologie der pflanzlichen Saprobien. *Berichte der deutsche botanischen Gesellschaft, 26A*, 505–519.

Kolkwitz, R., & Marsson, M. (1909) Okologie der tierischen Saprobien. Beitrae zur Lehre von des biologischen Gewasserbeurteilung. *Internationale Revue der Gesamten Hydrobiologie und Hydrographie, 2*, 126–52.

Kong, D. et al. (2012). Revision of ecological score of benthic macroinvertebrates community in Korea. *Journal of Korean Society on Environment, 34*, 251-69.

Kong, D.S., Park, Y., & Jeon, Y.R. (2018) Benthic Macroinvertebrates in Hongseong and Yesan County. Ministry of Environment (eds.), Natural Environment in Yesan, Seosan and Hongseong. Seoul: Korea.

Lee, S., Hwang, S., Lee, S., Hwang, H., &Sung, H. (2009) Landscape ecological approach to the relationships of land use patterns in watersheds to water quality characteristics. *Landscape and Urban Planning, 92*, 80–9.

Magurran, A.E. (1988) *Ecological diversity and its measurement*. Cambridge: Univ. Press.

McCafferty, P. (1981) *Aquatic entomology. The fisherman's and ecologists' illustrated guide to insects and their relatives*. Boston: Jones & Bartlett Publishers, Inc.

Merritt, R.W., & Cummins, K.W. (1996) *An introduction to the aquatic insects of North America. 3rd*. Iowa: Kendall/Hunt Publ. Co., Dubuque.

National Institute of Environmental Research (NIER). (2002) *The 2nd national ecosystem survey guide*. National Institute of Environmental Research, Seoul: Korea.

National Institute of Environmental Research (NIER). (2016) *Biomonitering survey and assessment manual*. NIER 2016 372.

Pielou, E.C. (1966) The measurement of diversity in different types of biological collection. *Journal of Theoretical Biology, 13*, 131-44.

Robarts, R.D., Barker, S.J., & Evans, S. (2008) Water quality monitoring and assessment: current status and future needs. Proceedings of Taal 2007: The 12th World Lake Conference, 165-75.

Shannon, C.E. & Weaver, W. (1998) *The measurement theory of communication*, Urbana: Univ. of Illinois Press.

Shikolmanov, I.A. (2000) Appraisal and assessment of world water resources. *Water International, 25*, 11-32.

Shin, Y.H. (1993) *Coloured insects of Korea.* Academy Press, Seoul: Korea.

Tsuda, M. (1964) *Biology of polluted waters*. Hokuryu-kan 1-258, Tokyo: Japan.

USEPA. (2003) Sampling and analytical procedures for GLNPO's open lake water quality survey of the Great Lakes; Chapter 4 - biological parameters; LG406 - standard operating procedure for benthic invertebrate field sampling procedure, revision 07. EPA 905-R-03-002.

Whittier, T.R., Stoddard, J.L., Larsen, D.P., & Herlihy, A.T. (2007) Selecting reference sites for stream biological assessments: Best professional judgment or objective criteria. *Journal of the North American Benthological Society, 26*, 349-60.

Won, D.H., Kong D.S., & Hwang, S.J. (2012) A multimetric benthic macroinvertebrate index for the assessment of stream biotic integrity in Korea. *Int. J. Environ. Res. Public Health, 9*, 3599-628.

Won, D.H., Kown, S.J., & Jun, Y.C (2005*) Aquatic insects of Korea*. Korea Ecosystem Service, Seoul: Korea.

Yoon, I.B. (1995) *An illustrated key book of aquatic insects of Korea*. Jung Hang Sa, Seoul: Korea.