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Species Composition of Benthic Macroinvertebrates and Water Evaluation Using Their Species in the Songji River in Korea

Byeong Ryong Lee[1] and Man Kyu Huh[2]*

[1]*Department of Biology Education, Seowon University, Cheongju 28674, Korea*
[2]*Division of Applied Bioengineering, Dong-eui University, Busan 47340, Korea*

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Benthic macroinvertebrates were analyzed in March, June, September, and December 2018 to evaluate water quality in the Songji River in Sacheon-ci, Korea. The identified benthic macroinvertebrates included 447 individuals belonging to 20 species, 18 families, 12 orders, 5 classes, and 3 phyla. Various ecological parameters were estimated for evaluation of the river status. The total ecological score of benthic macroinvertebrate community (TESB) varied from 17 (Station D) to 41 (Station A). The saprobic index and ecological score of benthic macroinvertebrate community (ESB) for the evaluation of river status revealed a water quality evaluation at Station A of II (oligosaprobic), indicating some satisfactory water protection. The benthic macroinvertebrate index (BMI) varied from 25.207 (Site C) to 39.348 (Station A). The evaluation of the river status at Stations C and D was polysaprobic, and sensitive taxa were absent. The mean Shannon-Weaver index (H´) of diversity varied from 1.288 (Station D) to 2.250 (Station A). The classification of saprobity based on H′ was β-mesosaprobic at Station A and α-mesosaprobic at the other stations. The value of geometric density was varied from 1.229 (Station A) to 2.071 (Station D), with a mean of 1.582. An artificial load is being added to this river. One of load is the rectal river construction which flows straight through the river physics. Thus, the environment of living organisms deteriorates due to insufficient water. In order to secure the quality of the Songji River and a good environmental habitat, several low-height stepped-beam structures are required.

Key words : Benthic macroinvertebrate index (BMI), dominance index (DI), Shannon-Weaver index (H´), Songji River, water quality

Introduction

River pollution is a major environmental problem that has negative effects for humans and wildlife alike. To prevent its consequences, the sources and severity of pollution must be determined by monitoring water quality in river basins, followed by the measures necessary to control the contamination [33].

A macroinvertebrate community structure is the basis of a water quality monitoring program, which is popular in many European countries and North America [24]. Many countries or states or water authorities have developed indices for biological assessment of water quality [15]. The index for biological assessment of water quality is an integrated assessment by monitoring habitat conditions, water quality, and organisms living in the water. The principle is that the summation of quality of both habitat and water can-reect the community structure of the organisms [24].

Benthic macroinvertebrates are aquatic bottom-dwelling (benthic) animals that can be seen with the naked eye (macro), but lack backbones (invertebrates). They live among the sediments and stones on the bottom of streams, rivers, and lakes. Benthic macroinvertebrates are the primary consumers in most systems and are an important link between primary resources and higher trophic levels, including many important recreational and commercial fish [6].

The importance of biological monitoring (biomonitoring) of water quality is recognized in many countries worldwide [1, 8, 27]. Benthic invertebrates have been favoured in environmental effects monitoring because they are sessile or limited in their range of movement and therefore can not avoid pollution [7]. Macroinvertebrates are particularly suitable indicators of the condition of lotic systems as they are found in almost all freshwater environments. Most macroinvertebrates are relatively sessile, which means they are ex-

***Corresponding author**
Tel : +82-505-182-6870, Fax : +82-51-890-1529
E-mail : mkhuh@deu.ac.kr

cellent for evaluating site-specific impacts, and collection methods are relatively easy, straightforward, and inexpensive. They are easy to sample and identify, and different taxa show varying degrees of sensitivity to pollution and other impacts [2].

According to the river Continuum Concept (RCC), the aquatic macroinvertebrate fauna responds to the physical changes along the riv er longitud inal gradient [30]. According to the RCC, shredders would be concentrated in headw ater sections, since they are highly dependent on alloct honous or ganic matter from the riparian zone.

A four-lane road crossing the river was established ten years ago and there were many changes from agricultural land to industrial factory. Three years ago, there was a construction of a straight river to prepare for the flood. Because a four-lane road crossing the river was established ten years ago and there were many changes from agricultural land to industrial factory, water quality and benthic macroinvertebrate changes are predicted.

The aim of this study is to define the macroinvertebrate fauna and its spatial and temporal distribution along thelongitudinal gradient of the Songji River at Sacheon-ci, Gyeongsangnam-do province in Korea. In addition, this study focuses on the application of saprobic extent and other ecological biodiversity methods for the assessment of river water quality.

Materials and Methods

Surveyed regions

This study was carried out on the Songji River (upper region: 35°011′014′′N/128°100′014′′E, low region: 35° 012′ 794′′N/128°049′459′′E), located at Yonghyeon-myeon province, Sacheon-ci in Korea (Fig. 1). The uplands of this river are usually no higher than 30 m above sea level. The length of the river is 5.2 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 agricultural fields and farming houses. Mean annual temperature ranges from -0.1 (January) to 25.7℃(August) with 13.1℃, and mean annual precipitation ranges from 19.2 (December) to 316.9 mm (August) with 1512.8 mm.

Sampling procedures

Benthic macroinvertebrates were conducted on March 3, June 2, September 1, and December 1, 2018 to investigate water quality evaluation using benthic macroinvertebrates at Songji River in Sacheon-ci, Korea. Sample collection was carried out the protocol of USEPA [29] Rapid Bioassessment Protocol III (RBP III) for benthic macroinvertebrates. All samples are picked in the field, a process facilitated by field-preservation of some samples. Benthic sampling was based on qualitative (a general assessment of the benthic taxa present, possibly with some observations of their relative abundance) and quantitative (an estimate of the numbers present so that a statistical confidence interval of the estimate can be calculated).

In case of implementing the multihabitat sampling method, the number of sub-samples (replicas) conforms to the percentage ratio of the bottom habitats, and a final composite sample representing represented for the monitoring si te is prepared.

Benthic macroinvertebrates are collected systematically from all available in-stream habitats by kicking the substrate

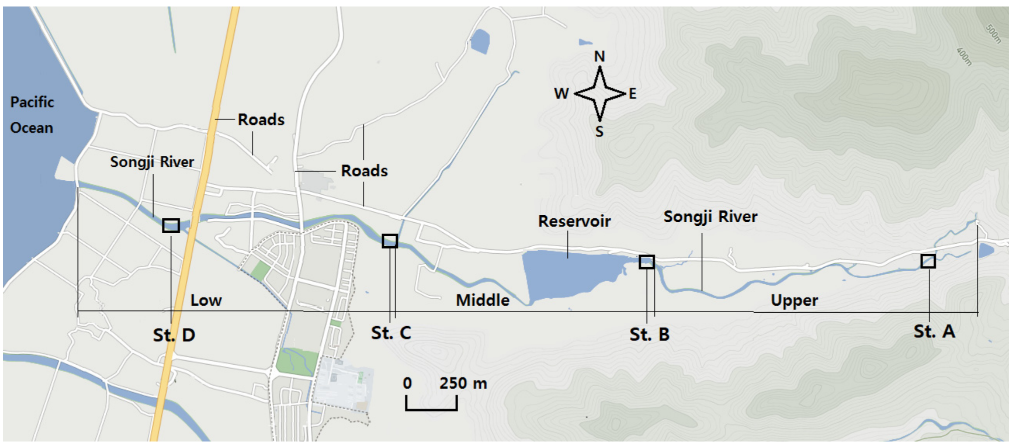

Fig. 1. Four sampling sites of the study area at Songji River.

Table 1. Classification scheme of the environmental quality score of benthic macroinverterates according to the indicator table from NIER [20]

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

or jabbing with a D-frame kick net with a mesh size of 500 µm 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. Sampling was carried out four times a year, from April 2018 to November 2018. Different taxa richness criteria were developed for each ecoregion to assign water quality classifications.

Taxonomic identification conducted by qualified professionals considered to be experts in the identification of aquatic invertebrates. Taxonomic identifications are checked against the most current and widely accepted list of names for a particular group [11, 14, 18, 26, 31, 32].

Water evaluation

Classification scheme of the environmental quality score of benthic macroinverterates according to the indicator table from NIER (Table 1) [20].

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

DI = (N1+N2)/N

N1 is the number of individuals in first dominant species and N2 is the 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 is the number of intolerant species and B is the number of tolerant species.

Total ecological score of benthic macroinvertebrate community (TESB) was calculated by the method of Kong et al. [13] (Table 2).

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

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. [13]

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

An analysis was conducted of the Benthic Macroinvertebrate Index (BMI), a biometric assessment technique using the large scale animals that appeared at each station (Table 3) [12].

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

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

An estimate of the number of individuals per unit area, obtained by estimating the density of each species in the group and summing across species. Defining *Dij* to be the mean density (number of individuals per unit area) across sites of species i in season j, the index for season j is $Aj = \Sigma\ Dij$.

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 [4].

Table 2. The scheme of ESB accrding to the phase of environmental quality [19]

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 3. Classification of benthic macroinvertebrates index (BMI) for the evaluation of river status [13]

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

Table 4. Classification of saprobity based on Shannon-Weaver's diversity, H′ [28]

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

The resulting relative abundance indices are then averaged: $Rj = 1/m\sum_{i=1}^{n} Dij/Di1$

Diversity, family richness and total abundance were used to summarise community data.

The Shannon-Wiener [25] diversity index (H′) was used, as it is not strongly influenced by rare taxa [23].

$$H' = -\sum pi \ln pi$$

*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 [5]. 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 [17]. 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 indices (E1~E5) was calculated using important value index of species [9, 22]. Classification of saprobity based on Shannon-Weaver's diversity, H′ (Table 4) [28].

Results

Species composition

From the four seasons survey on 2018 year, the identified benthic macroinvertebrates were 447 individuals belonged to 20 species, 18 families, 12 orders, 5 classes and 3 phyla. Mollusca accounted for only two taxa for four seasons within the four studied areas (Table 5). Annelida exhibited three species. Arthropoda exhibited greatest species diversity with 16 taxa identified. *Culicini* sp. exhibited greatest individuals (203) and second species was *Musca do-mestica* (65 individuals).

Water quality evaluation using benthic macroinvertebrates

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
Mollusca	2	4	2	4	1	4	1	3
Annelida	3	12	3	13	3	14	3	9
Arthropoda								
Malacostraca	1	4	1	3	1	6	1	6
Insecta	10	87	8	105	6	89	4	114
Total	16	107	14	125	11	113	9	132

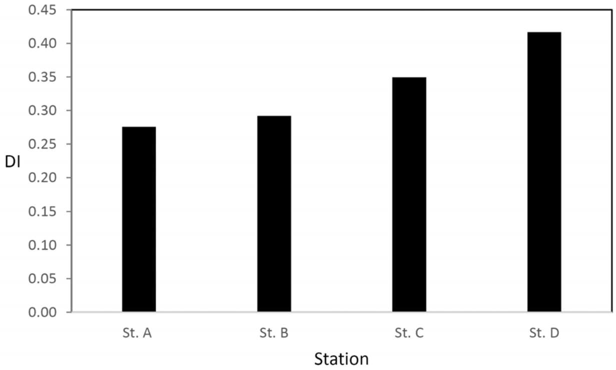

Fig. 2. Variability of the dominance indices (DI) of macroinvertebrate species at Songji River.

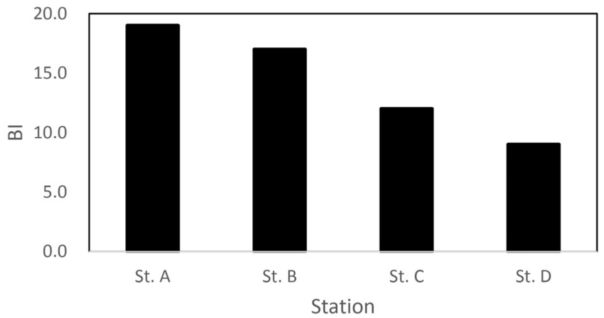

Fig. 3. Variability of the Beck-Tsuda's Biotic Index (BI) of macroinvertebrate species at Songji River.

The value of dominance index (DI) was varied from 0.276 (St. A) to 0.417 (St. D) with a mean of 0.333 (Fig. 2). DI was significantly different among the four regions. Beck-Tsuda's Biotic Index (BI) was varied from 9 (St. D) to 19 (St. A) with a mean of 14 (Fig. 3). BI was not shown significantly different among the four regions.

Total ecological score of benthic macroinvertebrate community (TESB) was varied from 17 (St. D) to 41 (St. A) with a mean of 29 (Table 6). Average ecological score of benthic macroinvertebrate community (AESB) was varied from 1.889 (St. D) to 2.563 (St. A) with a mean of 2.261. The saprobic

Table 6. 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	2.563	39.348
B	35	2.501	36.576
C	23	2.091	25.207
D	17	1.889	26.111
Mean	29	2.261	31.810

index and ESB for the evaluation of river status revealed that water quality at St. A was II (oligosaprobic) which means some satisfactory and protection water (Table 2). Environmental status at St. B was some defectiveness and area determination was improvement water. However, water quality at St. C and D was III (β-mesosaprobic). Environmental status at St. C and St. D was defectiveness and area determination was priority improvement water. Benthic macroinvertebrate index (BMI)) was varied from 25.207 (St. C) to 39.348 (St. A) with a mean of 31.810. 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. A and St. B was Very low species richness and most of the sensitive taxa were absent. The evaluation of river status at St. C and D was polysaprobic and Sensitive taxa are absent. Namely, several species were present or not and insensitive taxa showed high abundance or not.

We formed a composite index from points in time (four seasons) by taking the geometric mean of the indices. The result was shown in Fig. 4. Species strongly resistant to pollution were restricted to the upper stream, while the density was lower than those of low stations.

In order to assess macro-scale spatial variability of the animal community at Songji River, We analyzed distributions of species richness, diversity, and evenness of large taxonomic groups as well as four station compositions along a geographic distance (Table 7).

Water quality evaluation using biological diversity

Mean Shannon-Weaver index (H´) of diversity was varied from 1.288 (St. D) to 2.250 (St. A). H´ at the upper region (St. A) was higher than those of low region (St. D). Classification of saprobity based on Shannon-Weaver's diversity (H′)

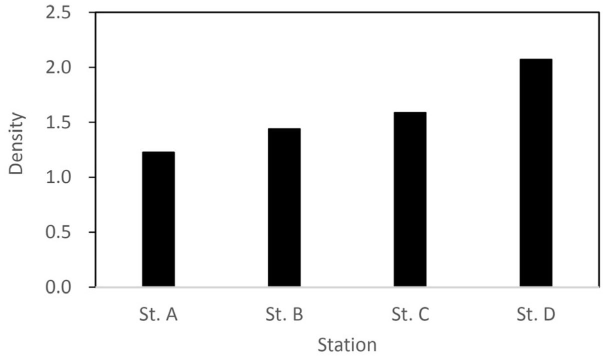

Fig. 4. The geometric mean of macroinvertebrate species at Songji River.

Table 7. Biological diversity index for invertebrates in the studied areas

Indices	St. A	St. B	St. C	St. D
Richness				
BPI	0.340	0.333	0.496	0.561
R1	3.060	2.507	2.115	1.638
R2	1.523	1.187	1.035	0.783
Diversity				
H′	2.250	1.927	1.672	1.288
N1	7.768	6.868	5.325	3.624
N2	5.523	4.904	3.421	2.572
Evenness				
E1	0.757	0.751	0.697	0.586
E2	0.518	0.528	0.484	0.403
E3	0.483	0.489	0.433	0.328
E4	0.664	0.714	0.642	0.710
E5	0.615	0.665	0.560	0.599

was β-mesosaprobic at St. A and α-mesosaprobic at other stations (Table 4). Berger-Parker's index (BPI) was varied from 0.333 (St. B) to 0.51 (St. D). N1 and N2 values were high at upper region. Richness indices for animal taxa were also varied among the stations and seasons. R1 and R2 values were high at upper region. 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-E4) except E5 were different from each other, there were not shown significant differences (p<0.05).

In this paper, the density of each species in the group and summing across species was shown in Fig. 4. The value of geometric density was varied from 1.229 (St. A) to 2.071 (St. D) with a mean of 1.582.

Discussion

Five years ago (2014), there was a species diversity including H′ and species richness in this area [10]. The previous studies in this area revealed species diversity including H′ and species richness were not very bad although water quality is not good condition. The H´ values for vertebrates in this river were 2.415 (St. A), 2.225 (St. B), 2.156 (St. C), and 1.862 (St. D). In this study, the H´ values were 2.250 (St. A), 1.927 (St. B), 1.672 (St. C), and 1.288 (St. D). Diversity has fallen in all four regions compared to three years ago. 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.

In this study, the high total richness and abundance were observed at the St. A. This has been reported in many fast-flowing streams with similar stream-beds [3, 16] and seems to be a general pattern in the forest streams [26]. It is due to the geographical characteristics of this river as a natural factor. Alpine stream-bed areas are likely to have high environmental stability and spatial heterogeneity, which may offer better conditions for fauna colonization.

There is a reservoir against the flood in this river (Fig. 1). Downstream of this river is almost dry on late fall, winter, and early spring. Therefore, many invertebrates are less likely to survive in the dry season and are less diverse. Artificial factors include stone construction and industrialization. In 2016, four-lane roads were built across the river. Contamination through automobiles enters rivers and poses a threat to the habitat of species. There are aeronautical industrial complexes around.

According with European Water Framework Directive requirements (EWFD), the class boundaries in quality classification are set using five ecological quality ratios (ERQ), *i.e.*, a numeric index showing the degree of deviation of any studied parameter from the initial reference value [21]. Extent of deviation is usually classified on a 5-level scale. According to the ERQ, Song Ji-cheon is evaluated the fourth grade based on several results of this study. The fouth grde is the value of the biological quality elements for the surface water body type deviate moderately from those normally associated with the surface water body type under undisturbed conditions. The values show moderate signs of distortion resulting from human activity and are significantly more disturbed than under conditions of good status. This river has been used as an agricultural incentive during the past years. In just ten years, industrialization has neglected water quality. Songji River main watercourse has been subjected to multiple discharges of wastewater, without previous treatment, due to strong industrial textile activity. This situation caused the deterioration of the water quality, resulting in water at low region of this river that is not only inappropriate for several uses, such as water supply for domestic and industrial use, recreation uses, but also dangerous for the public health.

Simply whether a study is spatially or temporal extensive will emphasize different aspects of ecosystem structure and function. Therefore, we suggest that adaptations of environmental indices are needed to refleco the real situation of this study area more accurately.

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초록 : 한국 송지천에서 저서성대형무척추동물의 종조성과 이를 이용한 수질 평가

이병룡[1] · 허만규[2*]
([1]서원대학교 생물교육과, [2]동의대학교 식품공학과)

저서성대형무척추동물은 수질 평가를 위해 다년간 이용되었다. 본 연구는 한국 송지천에서 저서성대형무척추동물을 이용하여 이 하천의 수질을 평가하고자 수행되었다. 동정된 동물은 3문 5강 12목 18과 20종 447개체였다. 집모기류(*Culicini* sp.)가 가장 우점종이었고(203개체), 두번째 우점종은 집파리(*Musca do-mestica*)였다. 다양한 생태학적 척도로 수질의 상태를 평가하였다. 전체 생태 점수(total ecological score of benthic macroinvertebrate community, TESB)은 17(St. D)에서 41(St. A)으로 평균은 29였다. St. A에서 부수성 지수와 저서성 대형무척추동물 생태 점수(ESB)는 II 등급으로 빈부수성, 수질은 약간 만족이며 보호가 요청되는 수질에 해당되었다. 저서성동물 지수(benthic macroinvertebrate index, BMI)은 25.207(St. C)에서 39.348(St. A)까지 이며 평균은 31.810였다. St. C와 St. D의 하천 상태 평가는 강부수성이며 민감종이 결여되어 있었다. 다양도를 나타내는 Shannon-Weaver index (H´)는 1.288(St. D)에서 2.250(St. A)였다. H′에 근거한 부수성 정도는 St. A에서는 β-중부수성이었으며 나머지 지점은 α-중부수성이었다. 지리적 밀도는 1.229(St. A)에서 2.071(St. D)으로 평균은 1.582였다. 송지천에서 사용한 무척추동물을 이용한 여러 수질의 척도는 한국 내 다른 하천에서도 적용할 수 있을 것이다.