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Development of Habitat-riparian Quality Indexing System as a Tool of Stream Health Assessment: Case Study in the Nakdong River Basin

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The major focus of this study is to evaluate a newly developed stream naturalness index system 'Habitat-riparian Indexing System (HIS).' There have been many studies that have assessed stream naturalness in order to provide information required for restoration. The results of these studies were enough for the purpose of the studies; however, the methodologies were limited especially with respect to rapid measurement and the representation of ecological habitats. Therefore, we derived crucial variables from a popularly utilized method and merged them with other criteria obtained from overseas approaches, resulting in the development of the HIS method. The stability of HIS was evaluated by comparing the results with the Stream Naturalness Index (SNI) of Cho (1997). We monitored 100 stream sites in the Nakdong River system using the two different methods for two sampling periods (spring and autumn), and the results were compared using statistical analyses. The determination coefficients between the index values from two methods were c.a. 0.6 for both seasons, and statistics revealed that HIS had a relatively higher stability, providing index values for stream environments. The results of this work suggest a possibility of the utility of HIS for other stream habitats.

Key words : Stream health evaluation, Stream Naturalness Index, Habitat-riparian Indexing System, method stability test, the Nakdong River basin, stream/river environment

INTRODUCTION

The assessment of stream health usually requires a lot of variables in order to convey sufficient information to researchers or managers; accompanying biological indexing systems for a comprehensive stream ecosystems conservation or management. Currently, stream management strategies in Korea tended to be restricted to hydrological, morphological and water quality dynamics. Water physical and chemical characteri-

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stics does not reflect all the information of stream ecological dynamics in general (Jeong *et al.*, 2006), therefore it is mandatory to implement both biological and environmental (including land use to water quality) monitoring simultaneously (Ministry of Environment, 2007).

The utility of stream naturalness evaluation system is encouraged when fast and simultaneous monitoring of a large number of sites is necessary. This method provides comprehensive information on water habitat and its surrounding environment due to the large number of parameters relating to the channel and riparian habitat, which facilitates its use in Korean freshwater ecosystems (Lee and Kim, 1999; Kim *et al.*, 2003; Park *et al.*, 2006; Ahn, 2007). Simultaneous monitoring of stream naturalness with biological entities such as benthic algae, macroinvertebrates, and fish will give a chance to observe the soundness or health of stream ecosystems. The Ministry of Environment in Korea initiated a national survey program for stream health assessment in 2007 to cover that biotic and abiotic information, and a broad-perspective environment evaluation tool is requested in order to compensate the limitation of information regarding habitat and riparian quality from microhabitat monitoring of biological entities.

In Korea, an excellent solution of stream naturalness indexing system was developed by Cho (1997). This method was a modified tool from the stream corridor assessment from the National Rivers Authority (1992) in England, which is appropriate to be utilized especially for Korean stream environments. Many of scientific research adopted this method (see Park *et al.*, 2003a) in order to obtain information for stream restoration guidelines and the current status of studied stream environments was successfully characterized. However, this indexing system is sometimes restricted to the following cases: (1) accompanied morphological measurement for streams is necessary to collect more accurate data, and (2) ambiguous expressions in questionnaires might cause partially biased results. The comparison of stream health among the studied streams is possible when multi sites monitoring is completed in a short term (e.g. one month in spring or autumn), so that easy-to-use method with a capacity of detecting overall stream characteristics is required.

The main focus of this study is to introduce a newly developed stream habitat and riparian quality monitoring tool. In this study, the aforementioned method was applied to stream monitoring sites, and the results were compared with other stream naturalness indexing system. The new method of measuring stream habitat and riparian quality, named the Habitat-riparian Indexing System (HIS) was applied to the Nakdong River basin (100 sites) to evaluate the stability of the method and its utilization efficiency. The main structure of the method was built by derivation of crucial variables from Cho (1997) (henceforth, this Cho's method is called as Stream Naturalness Index (SNI)) and some aspects that necessarily be considered in stream assessment were cited from Moss (1998). Those variables were modified to provide obvious expressions, and quantitative criteria also were adopted. We compared the results of the HIS and SNI methods as they were applied to the Nakdong River study sites, and the possible ways of utilizing the results from this method with biological characteristics were also discussed.

MATERIALS AND METHODS

1. Description of the survey programs and study sites

Two different monitoring programs were implemented in the Nakdong River basin in 2008. The spring monitoring was accomplished in April, and the autumn was in September. If rainfall occurred in the stream basin when field survey was arranged, the monitoring was postponed up to seven days in order to avoid the influence of concentrated rainfall.

One hundred study sites were distributed in the Nakdong River basin (Fig. 1). The list of descriptive information of the study sites is shown in the Appendix 1. The study sites mainly were distributed in the main channel and its tributaries. The site selection was based on the list of study site candidates from the Ministry of Environment (2007) in Korea. Thirty three sub-basins in the Nakdong River basin contain three sites on average, and they have at least one site.

2. Stream evaluation methods

We used two methods for the evaluation of the stream environments. The first method was Str-

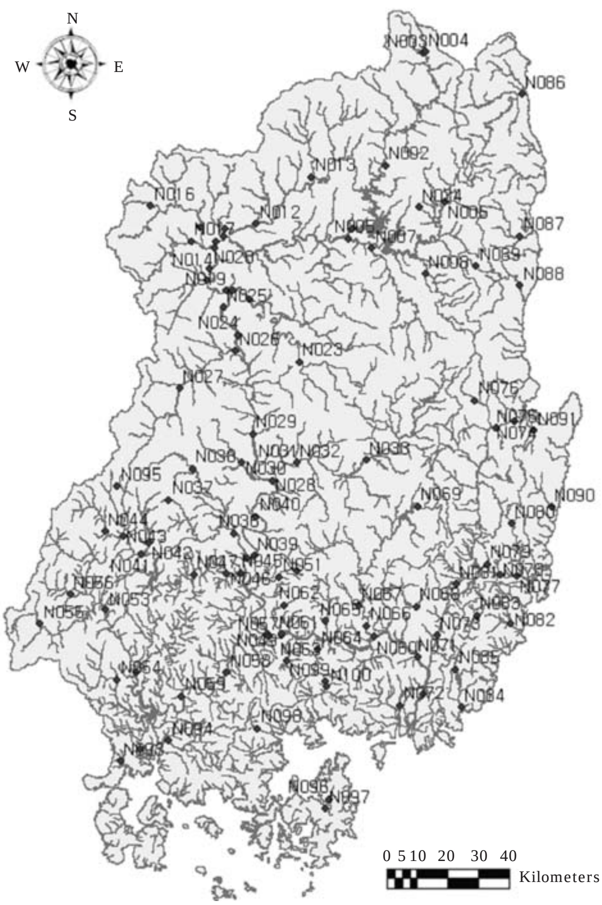

Fig. 1. Map of the study sites in the Nakdong River basin.

eam Naturalness Index (SNI) which was widely used in order to assess the stream environment in Korea (Cho, 1997). This method consists of 20 questionnaires, comprising six categories such as (1) development of stream channel, (2) characteristics of longitudinal cross-section and (3) lateral cross-section, (4) stream substrates, (5) land-water interactions, and (6) land-use of the basin. In this method, lower scores indicate better condition of the study site. Their applications were successful, and were able to detect the priority of stream restoration.

The second method utilized is "Habitat-riparian Indexing System (HIS)" prepared by the project of the Ministry of Environment (2007) (Table 1). Even though SNI is appropriate for the stream assessment for restoration, it is partially limited to some extent: for example, extensive field survey for stream morphology or habitat characteristics would be requested in order to obtain exact information of the stream circumstances. The HIS method has only 10 questionnaires, some of which were originally from SNI and the others from Moss (1998). Some detailed expressions in each of questionnaires were modified in order to provide possibility of easy-application and collecting crucial information for restoration of stream ecosystems. The survey form of the HIS can be utilized on the basis of eye-detection, and exact detection is not necessary. In contrast to SNI, the HIS produces high scores when the study site persist better condition (i.e. more natural or undisturbed).

In the first stage of the development of HIS method in 2007, we prepared total of 14 questionnaires in two different survey forms such as Habitat Quality and Riparian Quality (Ministry of Environment, 2007). These two methods were applied to 540 study sites in Korea, and we decided that some questionnaires were overlapped and those two survey forms had to be merged into one indexing system. At the final stage of HIS evolution, four questionnaires were neglected, and the remaining ten were modified.

3. Statistical analyses

Three simple statistical analyses were applied to the data set from the two survey programs. First, % difference of site index values and classification results were compared with each assessment method. Those two methods had different range of index values (i.e. HIS had range of 0～50 and SNI ranges 0～5), we first normalized all the index values in each survey program between 0～1 using minimum-maximum normalization. The normalized index values for the same sites in two survey programs then were used to calculate the % changes by dividing spring index value by autumn value and multiplied by 100 to get % difference. The average of % difference then was calculated to compare the difference of index values between seasons. The classification comparison was implemented by similar way. We counted the number of sites that had different classification results between the surveys, and calculated the % difference. These results can be used as indication of stability of method application.

Second, we calculated 'Coefficient of Variations (CV)' using the data sets (Zar, 2001). Mean and standard deviation (SD) values were calculated using four data sets (i.e. results from each me-

Table 1. Habitat-riparian Indexing System (HIS).

No.	Variables	Indications	Score	Criteria	Exceptions or remarks
1	Natural sandbars	Number of sandbars causing flow diversity in stream	5	More than 4 times	Objects for evaluation include sandbars, small islands and large rocks (rocks only for streams ordered 1～3)
			4	3 times	
			3	2 times	
			2	1 time	
			1	No sandbars	
2	Stream width	Ratio of channel width to land between water and levee (represented by *I*)	5	2.0＜I	$I=\frac{\sum_{i=1}^{11}\frac{\lvert d_i-w_i\rvert}{w_i}}{11}$, d_i, levee to levee width; w_i, channel width, i indicates the number of measurement of width at interval of 20 m. Even though the *I* value exceeds 2.0, Score 3 when simple ratio of channel width to levee width is less than 0.2
			4	1.5＜I≤2.0	
			3	1.0＜I≤1.5	
			2	0.5＜I≤1.0	
			1	I≤0.5	
3	Stream substrates	Dominant substrate patterns	5	Dominated by large rocks, round-shaped stones (＞256 mm)	Score 1 when: (1) no water in the fish way, (2) more than two weirs within the evaluation distance, or (3) serious sedimentation in the weir (average depth below 5 cm)
			4	Dominated by gravels-boulders, mostly round-shaped (partially presence of sand) (64～256 mm)	
			3	Mixture of small sharp gravels and sand, or sand dominant (8～64 mm)	
			2	Silt or mire (＜8 mm)	
			1	Concrete substrate	
4	Weirs	Obstacles for fish movement caused by artificial structures such as weir	5	No weirs	
			4	Bumpy, long length weir with gentle slope that enable fish to move upstream	
			3	Separate fish way with gentle slope	
			2	Fish way with steep slop	
			1	No or broken fish way	
5	Stream naturalness	Degree of morphological changes of stream	5	Naturally meandering	
			4	Partially modified but stream channel and levee meandering	
			3	levee straightened but channel meandering	
			2	levee and channel straightened but diverse channel width	
			1	Identical width of channel and levee	
6	Riparian changes	Modification of riparian characteristics	5	Naturally conserved	Use round-up average score when left and right side are differently managed. If there are too many patterns of changes, detect dominant pattern
			4	Natural materials such as wooden fence, artificial plantation	
			3	Stone piling with artificial plantation	
			2	Stone piling (water permeable)	
			1	Concrete (water impermeable)	

Table 1. Continued.

No.	Variables	Indications	Score	Criteria	Exceptions or remarks
7	Levee materials	Artificial or natural materials of levee	5	No artificial levee	Same remarks to Riparian changes
			4	Artificial soil levee with natural plantation or grass	
			3	Stone piling, near-natural block system with artificial plantation	
			2	Stone piling with near-natural block (water permeable)	
			1	Block system or concrete (water impermeable)	
8	Land use outside the levee	Dominant land use pattern outside the levee	5	Natural (grass, shrub, tree)	Prepare separate notice when the site has potential danger of enormous sediment loading or point/non-point source effluent during flood period
			4	Mixture of artificial and natural plantation	
			3	Mostly agricultural area or park. Small urbanized or residential area	
			2	Small agricultural area. Less than 1/2 of urbanization and residential area	
			1	More than 1/2 of urban or residential area	
9	Land use inside the levee	Impact of land use pattern inside the levee	5	Natural plantation, no artificial structures	
			4	Mixture of natural and artificial plantation (grassland)	
			3	Agricultural area	
			2	1/2 of park or exercise facility	
			1	Parking lot, water impermeable artificial structures	
10	Pollution control	Impact of point source and presence of water purification system	5	No point source	
			4	Presence of point source, with purification system	
			3	Presence of point source, without purification system, but scarce imapct	
			2	Presence of point source, without purification system, slightly impacting water quality	
			1	Presence of point source, without purification system, seriously impacting water quality	

thod at each of survey programs), and the CV values were obtained using the equation 1.

$$\text{Coefficient of Variations} = \frac{\text{SD}}{\text{Mean}} \times 100(\%) \qquad \text{(Eq. 1)}$$

The value of CV indicates the variation degree of each data set. Therefore, comparing CVs of two different survey programs with two methods can imply the stability of the surveys, i.e. the smaller the CV values, the more stable monitoring at each survey program.

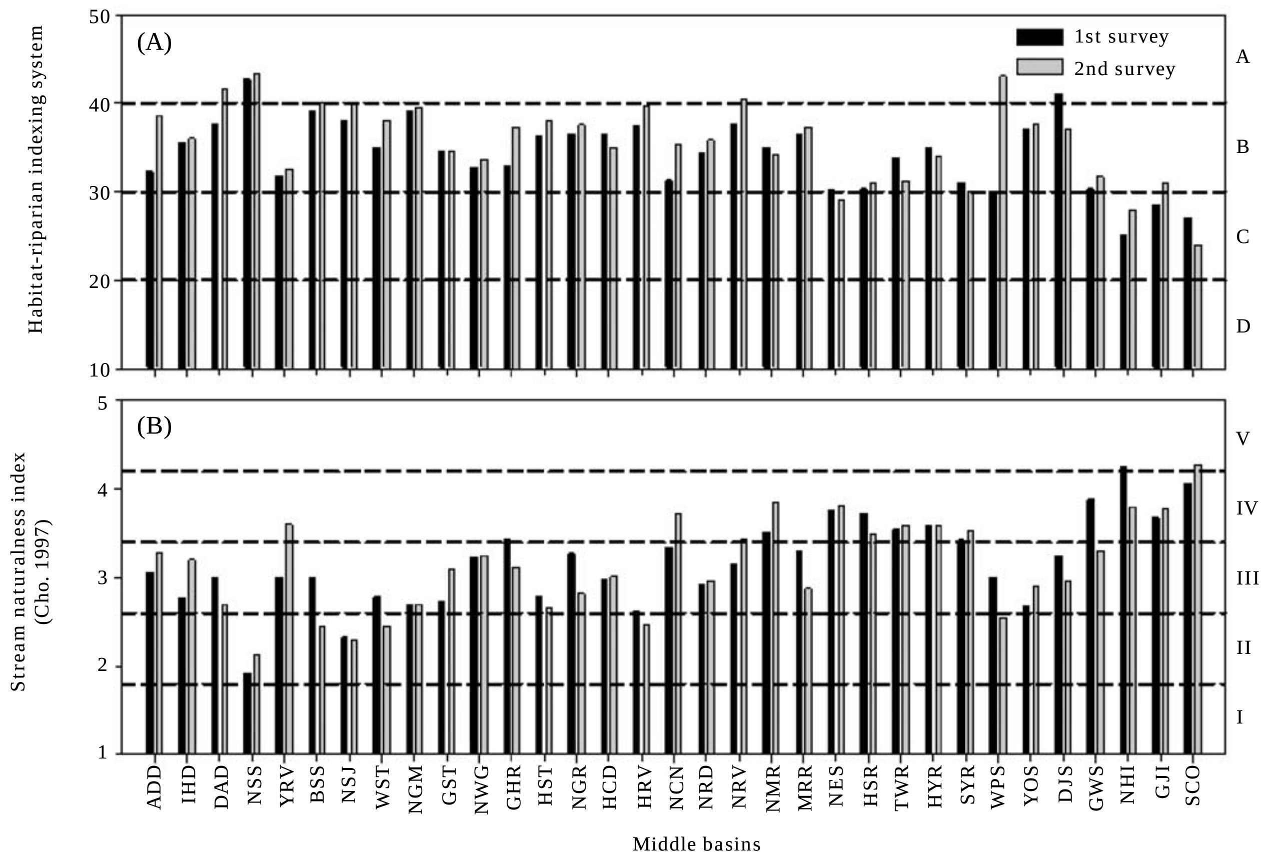

Fig. 2. Descriptive comparison of two different methods' index values in accordance with the sub-basins in the Nakdong River. A, HIS results; B, SNI results.

The third analysis was simple linear regression using four data sets. The comparison of SNI and HIS was implemented as the following: after completing the two survey forms, the scores for each of questionnaires of each form were used to characterize the current status of the study sites. The normalized scores (i.e. SNI) and summed scores (i.e. HIS) for all the study sites in the Nakdong River were compared using simple linear regression, and we determined how two methods had different results for the same study sites.

RESULTS

1. Distribution pattern of stream naturalness indices

Results of two survey programs using HIS and SNI are shown in the Fig. 2. The average ± SD of the two methods are as the following: at the first program, HIS, 34.22 ± 6.45; SNI, 3.18 ± 0.69; at the second program, HIS, 35.39 ± 6.64; SNI, 3.19 ± 0.67. The average results of the two methods could be translated into B and III classes respectively, which indicated the overall riparian characteristics of the Nakdong River basin was generally well managed.

Most of the study sites were at class B by HIS or class III by SNI (Table 2, 3). There were slight changes of the classes at the same sites in two different survey programs, but the overall pattern of distribution was similar to each program. Generally the study sites at higher classes (i.e. A and B of HIS and I and II of SNI) were distributed in the upper part of the river basin and the other classes were spread widely in the remaining basin. Especially classes D of HIS and V of SNI were found at the streams or rivers near urbanized area (e.g. Hyeongsan River in Pohang, Suyoung River in Busan, and Changwon Stream in Changwon Cities).

Table 2. Number of the study sites in each class by HIS at two survey programs.

Sub-basins	1st survey program				2nd survey program			
	A	B	C	D	A	B	C	D
ADD	1	1	1	1	2	1	1	
IHD		3	1			3	1	
DAD		2			1	1		
NSS	3				3			
YRV		3	1			3	1	
BSS		1				1		
NSJ		2				2		
WST		3				3		
NGM		2				2		
GST	1		1		1		1	
NWG		1	2			2	1	
GHR	1	1	2		2	1	1	
HST	1	3			1	3		
NGR		2				2		
HCD	2		2		2		1	1
HRV	1	1	1		1	2		
NCN		3	1			4		
NRD		4	1			4	1	
NRV		3			2	1		
NMR		6				4	2	
MRR		4			2	1	1	
NES		2	2			1	3	
HSR		2	1			2	1	
TWR		3	2			4	1	
HYR		2				2		
SYR	1			1	1			1
WPS		1	1		1	1		
YOS		2				2		
DJS	1	1			1	1		
GWS		1	2			2	1	
NHI			1				1	
GJI			2			1	1	
SCO		2		1			2	1
Sum (equals to %)	12	61	24	3	20	56	21	3

Table 3. Number of the study sites in each class by SNI at two survey programs.

Sub-basins	1st survey program					2nd survey program				
	I	II	III	IV	V	I	II	III	IV	V
ADD		2	1		1		1	2	1	
IHD		2	1	1				4		
DAD			2				1	1		
NSS	1	2					3			
YRV		2	1		1			2	1	1
BSS			1				1			
NSJ		2					2			
WST		1	2				3			
NGM		1	1					2		
GST		1	1				1		1	
NWG			2	1				2	1	
GHR			2	2				3	1	
HST		2	1	1			2	2		
NGR			1	1			1	1		
HCD	1	1		2		1	1		1	1
HRV	1		2				2	1		
NCN			2	2				1	3	
NRD		3	1		1		1	3	1	
NRV			3					1	2	
NMR			2	4					5	1
MRR			3	1			2	1	1	
NES			1	2	1			1	2	1
HSR			2		1			2		1
TWR			3	2				3	1	1
HYR				2					2	
SYR		1			1		1			1
WPS			2				2			
YOS		1	1				1	1		
DJS			1	1			1	1		
GWS				3			1		2	
NHI					1				1	
GJI			1	1					2	
SCO			1		2				1	2
Sum (equals to %)	3	21	41	26	9	1	27	34	29	9

2. Stability of HIS

HIS had smaller variations when we compared the changes of classes between two survey programs. From the comparison of % difference of normalized index values, HIS had 99.7% difference between spring and autumn monitoring while SNI had 123%. The similarity of classes between two programs of HIS was 73% and SNI showed 52% of similarity. There was no increase or decrease of similarity by two or more classes, and all the changes were within one class. Comparing spring and fall, total 19 sites' classes were increased and 8 was decreased from HIS, by contrast, 23 sites' classes were increased and 25 sites were decreased from SNI.

The CV values for each of methods were as the following: at the first program, HIS, 18.9%; SNI, 21.7%; at the second program, HIS, 18.8%; SNI, 21.1%. From the results, HIS had relatively smaller variation in the survey results compared with SNI (c.a. 3%), and between the programs, there was almost no difference from HIS, compared with SNI.

Fig. 3 shows the comparison of results from both stream naturalness indices. The determi-

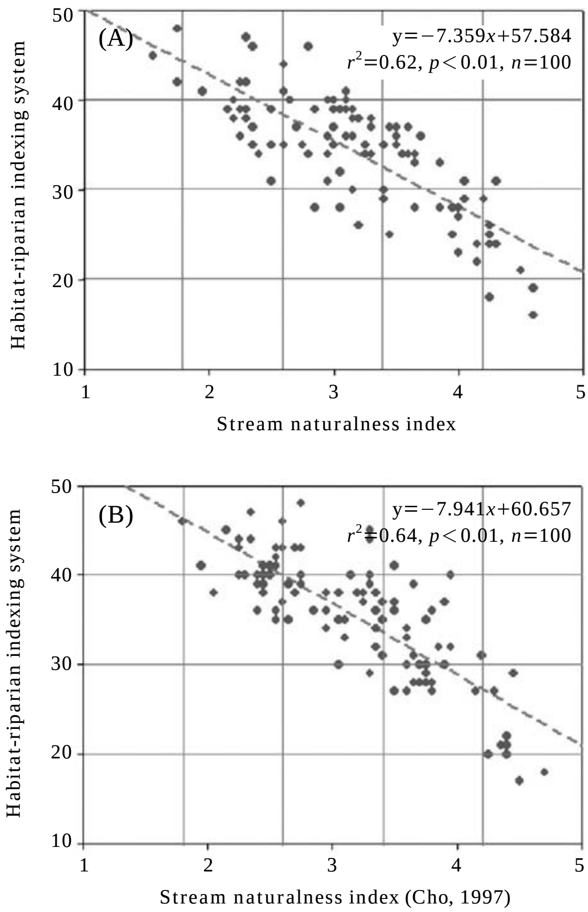

Fig. 3. Simple linear regression analysis using data sets of two different methods. A, comparison of spring monitoring results; B, comparison of autumn results.

nation coefficient between two methods were high for two survey programs (r^2=0.62 and 0.64, $p<0.01$, n=100 respectively). Because of the different indexing processes, negative relationship between HIS and SNI was detected. The slope and intercept of the two regression line had relatively small differences, which imply there was small discrepancy of the survey results.

DISCUSSION

The newly developed HIS has satisfactory stability on the stream environment monitoring. Compared with SNI, HIS had smaller difference of site classification between two surveys, which may imply the possibility of stable application of HIS to the stream sites. There are four possible reasons for the % difference results: (1) different viewpoints among observers, (2) seasonality of the stream characteristics, (3) different ranges of classification in two methods, and (4) expressions of criteria. We prepared the monitoring plan as observing the stream sites by unified viewpoint, so that the same person evaluated all of the study sites. Therefore, the first reason might be overcome by this effort. The variables that can be affected by seasonality is Natural sandbars, Stream width in HIS and Sandbars in SNI, which relies on the current stream discharge. The other variables in both methods are regarding physical or morphological aspects and the surrounding environments of streams. Therefore, seasonality is also not seriously affecting the total changes of index values.

The third and fourth reasons are more crucial for the differences. HIS had only four classes while SNI had five, which in turn makes the classification using the index values tight. For HIS, one class had a range of 10 (when averaged by the number of variables, 1) between the adjacent classes, but SNI had 0.8. The changes of index values of SNI may easily cause the changes of classification, which can be thought as the primary reason for the difference of classification. The fourth factor is believed to affect the difference of index values. Quantified and intuitive expressions in criteria may help users of the methods understand the ultimate intention of each variable. Even though all the observers in this study had enough discussion before every monitoring, the second monitoring results tended to be more accurate than the first. In this situation, the stability of evaluation method becomes more important because the user-originated bias of monitoring results has to be compensated by the method itself. In this point of view, HIS is believed to be successful in stability of application.

The advantages of using HIS can be summarized as the following: (1) smaller number of questionnaires and their intuitive expressions (sometimes quantified classification criterion) can increase the speed and accuracy of monitoring, (2) Small variations between different monitoring results at the same study sites (without considering seasonality factor), and (3) minimum necessary information that should be examined. Larger numbers of questionnaires from SNI can provide more information regarding the current status of the study sites, in contrast indicating that HIS may have to overcome the loss of stream health information compared with SNI. However, general patterning or assessing tendency of the sites characteristics can be identified by HIS.

It is possible to compare biological characteristics of stream habitats with the index values and classification results of HIS. Ordination methods such as PCA or CCA can be solutions, and recently emerged Ecological Informatics is another solution for the explanation and analysis of complex ecosystem dynamics to identify the relationship between biological entities and the stream environments (Park *et al.*, 2003b; Park *et al.*, 2004; Joo and Jeong, 2005; Jeong *et al.*, 2006; Kim *et al.*, 2007; Park *et al.*, 2007; Jeong *et al.*, 2008).

CONCLUSION

In this study, we implemented comparison of stream ecosystem indexing using two different methods such as Habitat-riparian Indexing System (HIS) and Stream Naturalness Index from Cho (1997). All 100 study sites in the Nakdong River basin were monitored using those methods for two times (Spring and Autumn), and the results were compared with statistical analysis. The determination coefficients between the index values from two methods were c.a. 0.6 for both seasons, and the following statistics revealed that HIS was stable in producing index values for the stream environments. The results of this work can be used as an evidence for the utility of HIS for other stream habitats.

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Appendix 1. Descriptive information of the study sites in the Nakdong River basin.

No.	Name of sub-basins	Abbreviation of the names	Number of study sites	Name of the sites
1	Andong Dam	ADD	4	N001～N004
2	Imha Dam	IHD	4	N005～N008
3	Downstream Andong Dam	DAD	2	N009～N010
4	Naesung Stream	NSS	3	N011～N013
5	Young River	YRV	4	N014～N017
6	Byeongsung Stream	BSS	1	N018～N018
7	Nakdong Sangju	NSJ	2	N019～N020
8	Wi Stream	WST	3	N021～N023
9	Nakdong Gumi	NGM	2	N024～N025
10	Gam Stream	GST	2	N026～N027
11	Nakdong Waegwan	NWG	3	N028～N030
12	Geumho River	GHR	4	N031～N034
13	Hoi Stream	HST	4	N035～N038
14	Nakdong Goryeong	NGR	2	N039～N040
15	Hapchon Dam	HCD	4	N041～N044
16	Hwang River	HRV	3	N045～N047
17	Nakdong Changnyeong	NCN	4	N048～N051
18	Nam River Dam	NRD	5	N052～N056
19	Nam River	NRV	3	N057～N059
20	Nakdong Miryang	NMR	6	N060～N065
21	Miryang River	MRR	4	N066～N069
22	Nakdong Estuary	NES	4	N070～N073
23	Hyeongsan River	HSR	3	N074～N076
24	Taewha River	TWR	5	N077～N081
25	Hoiya River	HYR	2	N082～N083
26	Suyoung River	SYR	2	N084～N085
27	Wangpi Stream	WPS	2	N086～N087
28	Youngduk-oship Stream	YOS	2	N088～N089
29	Daejong Stream	DJS	2	N090～N091
30	Gawha Stream	GWS	3	N092～N094
31	Namhae Island	NHI	1	N095～N095
32	Geoje Isalnd	GJI	2	N096～N097
33	Southern Coast	SCO	3	N098～N100

Appendix 2. List of index values and classification results by two different methods in two survey programs.

Sub-basin	Sites	1st survey program				2nd survey program			
		HIS		Cho (1997)		HIS		Cho (1997)	
		Index	Class	Index	Class	Index	Class	Index	Class
ADD	N001	19	D	4.6	V	30	C	3.9	IV
	N002	46	A	2.35	II	45	A	3.3	III
	N003	36	B	2.25	II	41	A	2.55	II
	N004	28	C	3.05	III	38	B	3.35	III
IHD	N005	28	C	4	IV	29	C	3.3	III
	N006	39	B	2.15	II	38	B	3.25	III
	N007	35	B	2.75	III	39	B	3.3	III
	N008	40	B	2.2	II	38	B	2.95	III
DAD	N009	36	B	3.15	III	40	B	3.15	III
	N010	39	B	2.85	III	43	A	2.25	II
NSS	N011	41	A	1.95	II	41	A	1.95	II
	N012	45	A	1.55	I	45	A	2.15	II
	N013	42	A	2.25	II	44	A	2.25	II
YRV	N014	38	B	2.2	II	35	B	3.1	III
	N015	32	B	3.05	III	33	B	3.6	IV
	N016	26	C	4.25	V	22	C	4.4	V
	N017	31	B	2.5	II	40	B	3.3	III
BSS	N018	39	B	3	III	40	B	2.45	II
NSJ	N019	37	B	2.35	II	40	B	2.3	II
	N020	39	B	2.3	II	40	B	2.3	II
WST	N021	34	B	3.25	III	35	B	2.55	II
	N022	37	B	2.7	III	39	B	2.4	II
	N023	34	B	2.4	II	40	B	2.4	II
NGM	N024	39	B	2.3	II	39	B	2.65	III
	N025	39	B	3.1	III	40	B	2.75	III
GST	N026	41	A	2.6	II	41	A	2.45	II
	N027	28	C	2.85	III	28	C	3.75	IV
NWG	N028	28	C	3.65	IV	28	C	3.65	IV
	N029	30	C	3.4	III	35	B	3.4	III
	N030	40	B	2.65	III	38	B	2.7	III
GHR	N031	25	C	3.95	IV	27	C	3.6	IV
	N032	30	C	3.15	III	31	B	3.4	III
	N033	35	B	3.5	IV	43	A	2.7	III
	N034	41	A	3.1	III	48	A	2.75	III
HST	N035	34	B	2.95	III	38	B	2.45	II
	N036	35	B	2.35	II	36	B	2.85	III
	N037	42	A	2.3	II	44	A	2.35	II
	N038	34	B	3.55	IV	34	B	2.95	III
NGR	N039	36	B	2.95	III	37	B	2.6	II
	N040	37	B	3.6	IV	38	B	3.05	III
HCD	N041	48	A	1.75	I	46	A	1.8	I
	N042	47	A	2.3	II	47	A	2.35	II
	N043	23	C	4	IV	20	D	4.4	V
	N044	28	C	3.85	IV	27	C	3.5	IV
HRV	N045	42	A	1.75	I	40	B	2.25	II
	N046	40	B	2.95	III	43	A	2.75	III
	N047	30	C	3.15	III	36	B	2.4	II

Appendix 2. Continued.

Sub-basin	Sites	1st survey program				2nd survey program			
		HIS		Cho (1997)		HIS		Cho (1997)	
		Index	Class	Index	Class	Index	Class	Index	Class
NCN	N048	36	B	3.1	III	34	B	3.35	III
	N049	25	C	3.45	IV	35	B	3.75	IV
	N050	33	B	3.85	IV	40	B	3.95	IV
	N051	31	B	2.95	III	32	B	3.85	IV
NRD	N052	39	B	2.25	II	38	B	2.05	II
	N053	35	B	2.6	II	36	B	2.85	III
	N054	35	B	3	III	37	B	3.4	III
	N055	39	B	2.5	II	39	B	2.75	III
	N056	24	C	4.3	V	29	C	3.75	IV
NRV	N057	39	B	3.15	III	44	A	3.3	III
	N058	37	B	3	III	41	A	3.5	IV
	N059	37	B	3.3	III	36	B	3.5	IV
NMR	N060	36	B	3.1	III	37	B	3.9	IV
	N061	35	B	3.5	IV	34	B	3.6	IV
	N062	31	B	4.05	IV	29	C	4.45	V
	N063	33	B	3.65	IV	30	C	3.7	IV
	N064	38	B	3.3	III	36	B	3.8	IV
	N065	37	B	3.5	IV	39	B	3.65	IV
MRR	N066	34	B	3.65	IV	30	C	3.75	IV
	N067	34	B	3.3	III	35	B	2.65	III
	N068	38	B	3.15	III	43	A	2.6	II
	N069	40	B	3.1	III	41	A	2.5	II
NES	N070	22	C	4.15	IV	22	C	4.25	V
	N071	38	B	3.2	III	38	B	3.2	III
	N072	37	B	3.45	IV	29	C	3.65	IV
	N073	24	C	4.25	V	27	C	4.15	IV
HSR	N074	21	C	4.5	V	21	C	4.4	V
	N075	35	B	3.25	III	36	B	2.95	III
	N076	35	B	3.4	III	36	B	3.1	III
TWR	N077	24	C	4.15	IV	21	C	4.35	V
	N078	40	B	3	III	32	B	3.05	III
	N079	39	B	3.05	III	37	B	3.25	III
	N080	37	B	3.3	III	35	B	3.05	III
	N081	29	C	4.2	IV	31	B	4.2	IV
HYR	N082	36	B	3.5	IV	37	B	3.5	IV
	N083	34	B	3.65	IV	31	B	3.65	IV
SYR	N084	18	D	4.25	V	17	D	4.5	V
	N085	44	A	2.6	II	43	A	2.55	II
WPS	N086	26	C	3.2	III	40	B	2.5	II
	N087	34	B	2.8	III	46	A	2.6	II
YOS	N088	39	B	2.85	III	39	B	2.45	II
	N089	35	B	2.5	II	36	B	3.35	III
DJS	N090	46	A	2.8	III	42	A	2.55	II
	N091	36	B	3.7	IV	32	B	3.35	III
GWS	N092	29	C	4.05	IV	31	B	3.65	IV
	N093	28	C	4	IV	28	C	3.7	IV
	N094	34	B	3.6	IV	36	B	2.55	II
NHI	N095	25	C	4.25	V	28	C	3.8	IV
GJI	N096	29	C	3.4	III	30	C	3.6	IV
	N097	28	C	3.95	IV	32	B	3.95	IV
SCO	N098	34	B	3.3	III	27	C	3.8	IV
	N099	16	D	4.6	V	18	D	4.7	V
	N100	31	B	4.3	V	27	C	4.3	V