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Note

Relationships among a Habitat-Riparian Indexing System (HIS), Water Quality, and Land Coverage: a Case Study in the Main Channel of the Yangsan Stream (South Korea)

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In this study a total of 27 stream sites, at 1 km intervals, were monitored for simple physicochemical water characteristics, land coverage patterns, and stream environment characteristics using the Habitat-riparian Indexing System (HIS), in the Yangsan Stream. The HIS has been tested in previous research, resulting in some identification of advantages in the application to the stream ecosystems data. Even though reliable stream environment characterization was possible using HIS, there was no information about the application of this tool to present continuity of environmental changes in stream systems. Also the necessity was raised to compare the results of HIS application with land coverage information in order to provide useful information in management strategy development. The monitoring results of this study showed that changes of environmental degradation were well represented by HIS. Especially, stream environment degradation due to construction was relatively well reflected in the HIS monitoring results, and the main causality of Yangsan Stream degradation was expansion of the urbanized area. In addition, there were significant relationships between the HIS scores and land coverage information. Therefore, it is necessary to prepare appropriate options in controlling or managing the expansion of the industrialized areas in this stream basin in order to improve the stream environment. For this purpose, ensemble utilization of HIS results, water quality, and geographical information, resulting in integration with remote sensing processes can be possible.

Key words : Habitat-riparian Indexing System (HIS), stream characteristics, Yangsan Stream, land coverage, water quality

INTRODUCTION

Stream health evaluation requires the simultaneous observation of numerous parameters, in order to provide an accurate diagnosis for the selected streams or stream sites (National Institute of Environmental Research, 2008). Diagnosis of stream health can be divided into two methods: biological characterization-monitoring biological entities, such as benthic diatoms, macroinvertebrates, and fish that reside in the streams, or stream physical environment monitoring including habitat and riparian patterns. The former is mandatory in order to obtain accurate information of stream 'ecosystem' health. However, not only does the seasonality of biological entities but also the high cost for monitoring often exacerbate the steam health monitoring process, even though they are necessary for ecological characterization. The lat-

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ter can be fast applied to the stream systems, to investigate the degradation of environmental factors (Lee and Kim, 1999; Kim *et al*., 2003; Park *et al*., 2006; Ahn, 2007).

The Habitat-riparian Indexing System (HIS) was reported as a good solution for the detection and diagnosis of environmental degradation in stream systems (Jeong *et al*., 2008). The Stream monitoring results using the HIS in the Nakdong River basin revealed the following advantages: (1) fast monitoring, (2) intuitive expression, and (3) monitoring result stability. As aforementioned, an accurate assessment of stream ecosystem health needs to combine both biological and non-biological characteristics, but pre-monitoring using the HIS in a stream system can provide basic information about the status of stream environment. The biological investigation can be accompanied later with the HIS monitoring if necessary. However, Jeong *et al*. (2008) successfully tested this tool in different stream systems involving wide spectrum of environment characteristics (large river to small mountainous streams, urbanized and well preserved streams), they were failed to compare a continuous changes of the scores along with the stream pathway. This is an important issue because current stream restoration activities in South Korea are not restricted at one site but at least reach level of stream is under consideration.

Furthermore, it is important to discover the relationship between the stream environmental characteristics with land coverage information. Land cover is a good information source for stream characterization because it conveys knowledge of possible anthropogenic impacts to the stream. Various scientific research projects have been implemented to assess out the relationship between land cover and stream ecosystem characteristics (e.g. Lammert and Allan, 1999; Pan *et al*., 1999;

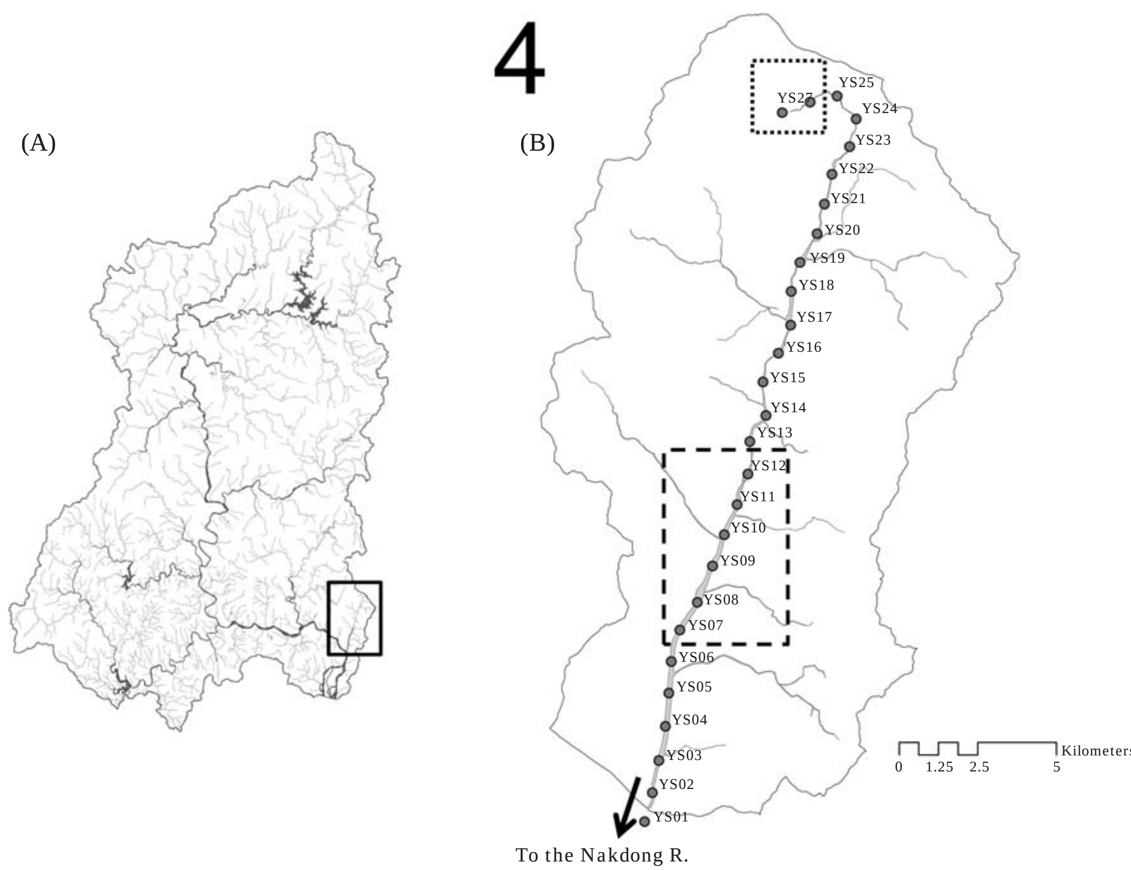

Fig. 1. Map of the study sites. A, Map of the Nakdong River basin and the location of the Yangsan stream; B, the Yangsan Stream basin and the distribution of the study sites. Solid box in panel A indicates the location of the Yangsan Stream; broken box in panel B indicates the downtown area of the Yangsan City; dotted box in panel B indicates the location of the Tongdo Temple area.

Table 1. Devices and methods applied to the environment and water quality monitoring

Environment factors	Units	Device models or applied method
Stream width	m	YardagePro / Bushnell / US
Water temperature	°C	
Dissolved oxygen	mg L^{-1} % saturation	DO, Conductivity, Salinity, and Temperature Mete (Model 85) / YSI Inc. / US
Conductivity	μs cm^{-1}	
pH		pH meter (Model 3-star) / ThermoScientific / US
Turbidity	NTU	Turbidimeter (Model Micro 100) / HF Scientific / US
Alkalinity	mg L^{-1}	Standard Methods (method No. 2320; Eaton *et al.*, 1995)

Fore and Grafe, 2002; Sutherland *et al.*, 2002), however most of the research applied to Korean streams were biased towards hydrological management.

In this study, we monitored a small stream system, the Yangsan Stream located in the southeastern part of the Nakdong River basin, to evaluate the utility of HIS for the representation of environmental continuity. In addition, land coverage patterns at the study sites in the stream as well as some basic water physicochemical characteristics were simultaneously monitored during the study period, in order to discuss further utility of the HIS tool for the stream environment management.

The Yangsan Stream flows 32.3 km and covers ca 243 km^2, originated from Chuiseo Mountain in Habook Myeon, Kyeongsangnamdo Province. This stream locates in the Southeastern area of the Nakdong River basin, and confluent to the River. The confluent site is ca 20 km upper from the Nakdong Estuarine Barrage. About 220,000 residents are in the stream basin currently, and mostly the stream is utilized as agricultural and industrial water resource. In recent decades, not only the size of population but also the number / area of industrial complexes exhibited a gradual tendency of increase (Park *et al.*, 1999), which is believed as the primary factor affecting stream water quality deterioration (Han *et al.*, 1984; Chung *et al.*, 1992; Kim *et al.*, 1992). Therefore, Yangsan Stream can be recognized as an urbanized and industrialized lotic system, which enabled us to evaluate the HIS for a disturbed stream ecosystem with respect to land coverage and water quality. A total of 27 study sites were prepared for the evaluation in the main channel of Yangsan Stream (1 km interval; the first site, 100 m upstream from the confluence with the Nakdong River; Fig. 1).

The HIS is provided in Jeong *et al.* (2008), which is a tool evaluating the naturalness and health of stream environments. It consists of 10 questionnaires such as natural sandbars, stream width, stream substrates, weirs, stream naturalness, riparian changes, levee materials, land use in- and outside the levee, and pollution control. In this study, all 27 study sites were monitored using HIS. In order to minimize bias of monitoring results, one scientists specialized in freshwater ecology applied the tool to every study site. Monitoring was conducted at every center point of study sites where overall characteristics of a study site could be observed. Each monitoring site extends 500 m up- and downstream from the center point respectively, resulting in total 1,000 m in the evaluation at every site. For more information about the tool expression, limitation, relationship between stream physical components such as river flow, and leveling system, the readers are referred to consult Jeong *et al.* (2008). Basic physicochemical characteristics were monitored at each study site, listed in the Table 1. We implemented one sampling program, consisting of three sampling days within one week, to minimize discrepancy of water physicochemical characteristics.

We used land coverage data (raster type; 30 m resolution) produced by the Ministry of Environment, developed in 2006, to compare the land coverage, water quality and HIS data. The land coverage consisted of seven categories such as urbanized, agricultural, forest, grassland, wetland, open land, and water area. In order to obtain land coverage data for each of study sites, 27 circle-type buffer areas (radius 1 km) were produced for every study site. The areal information of seven land coverage types in each of buffer areas then used in the comparison with water quality and HIS data, using Pearson correlation (α=0.05).

There were variations of physicochemical parameters in the main channel of the Yangsan Stream

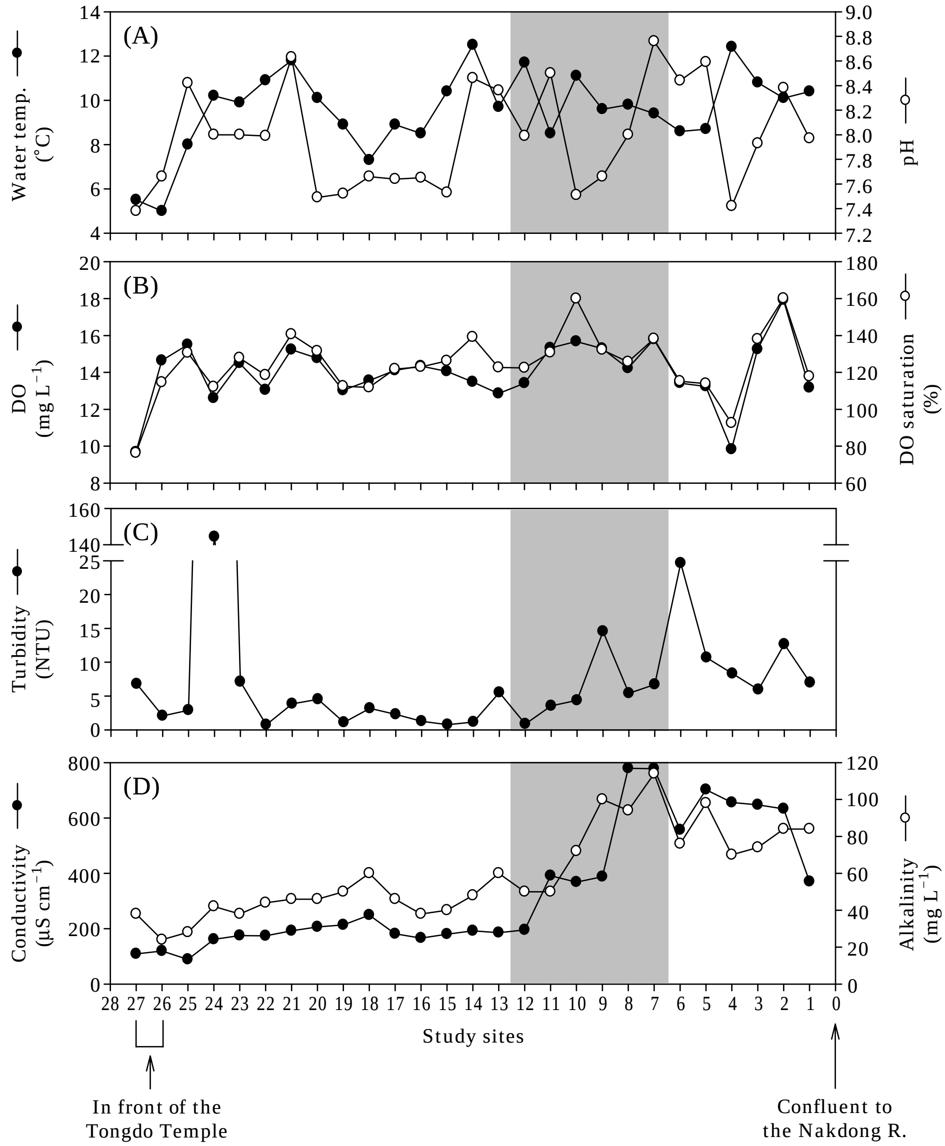

Fig. 2. The variations of physicochemical characteristics along with the stream. A, water temperature and pH; B, DO concentration and %saturation; C, turbidity; D, conductivity and alkalinity.

(Fig. 2). The sites close to the Tongdo Temple (i.e. YS27 and 26) showed relatively well preserved conditions, while the urbanized reach showed degraded characteristics. Among the water quality parameters, conductivity and alkalinity were the most dynamic parameters varied longitudinally. They had a slight and gradual increase progressing downstream and a sharp increase was detected in the downtown segment. The lowest values of the two parameters were detected at the temple area, and the lower part of the stream (i.e. YS01 to YS06) exhibited increased level of conductivity and alkalinity.

Fig. 3. illustrates the variation of HIS results and land coverage data at the study sites. The HIS scores varied along with the main channel, and the headwater area showed the highest scores in the stream (Fig. 3A). The area where the Yangsan Stream flows through the downtown area of the Yangsan City exhibited mostly degraded characteristics.

Land coverage showed clear and distinct difference between headwater, middle and lower reach of the stream (Fig. 3B). In the headwater reach

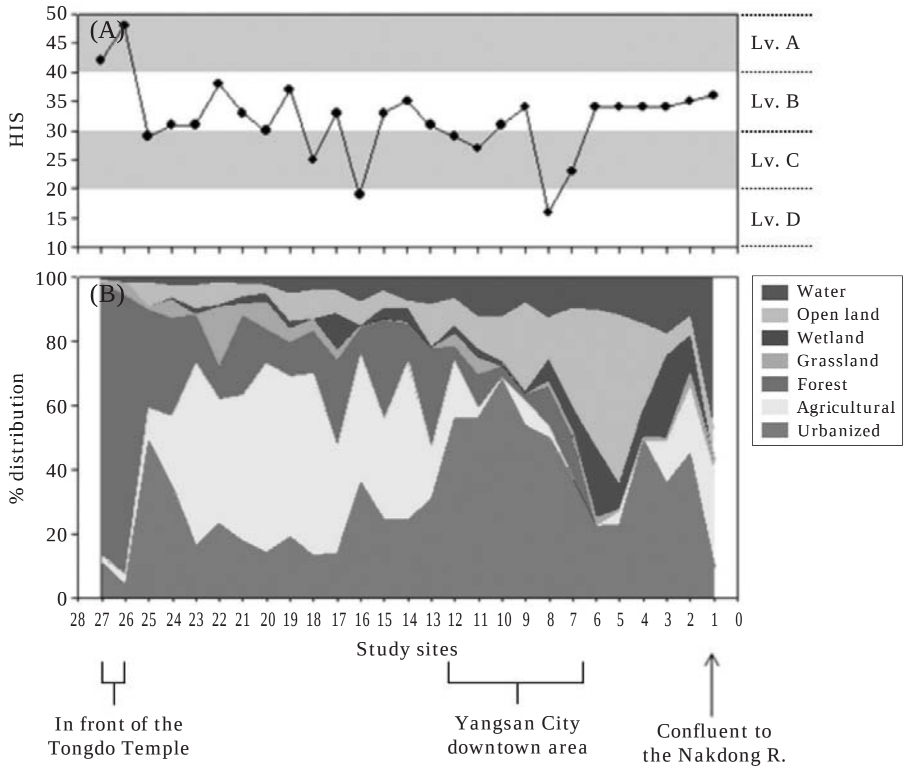

Fig. 3. The changes of HIS scores and land coverage patterns along with the stream. A, HIS scores obtained at each study site and the stream health level; B, land coverage changes in the stream.

Table 2. Correlation matrix for water quality, land coverage and HIS data. WT, water temperature; Cond., conductivity; Alkal., alkalinity; Turb., turbidity; Urban., urbanized; Agri., agricultural; Grass., grassland; Wet., wetland; Open., open land. *indicates $p < 0.05$, **for $p < 0.01$ at $\alpha = 0.05$

Parameters		Water quality							HIS
		WT	DO	DO%	pH	Cond.	Alkal.	Turb.	
Land coverage	Urban.	0.37	0.30	0.42*	0.12	0.38*	0.33	0.12	−0.46*
	Agri.	0.21	0.05	0.10	−0.17	−0.51**	−0.42*	−0.16	−0.06
	Forest	−0.66**	−0.28	−0.43*	−0.24	−0.52**	−0.56**	0.00	0.46*
	Grass.	0.10	−0.02	−0.05	0.00	−0.17	−0.20	0.07	0.18
	Wet.	0.16	0.17	0.16	0.23	0.62**	0.39*	0.00	0.01
	Open.	0.03	−0.09	−0.09	0.34	0.65**	0.70**	0.09	−0.13
	Water	0.25	0.01	0.09	0.10	0.46*	0.53**	−0.03	−0.05
HIS		−0.20	−0.25	−0.27	−0.20	−0.30	−0.28	0.01	1

(i.e., YS27 and YS26), the area of forest dominated the buffer circle (more than 80%). Small % distribution of urbanized area at the YS27 site was due to the Tongdo Temple. Immediate after the temple boundary, agricultural land use dominated the land coverage, and forest area sharply decreased. When the stream encountered the city center, urbanized land area drastically increased, up to 50 to 60%. After this area, the dominant land coverage transited to open land type, and water area gradually expanded.

It was apparent that some parameters in three data groups (i.e. water quality, land coverage, and the HIS score) exhibited significant correlation (Table 2). The parameters that frequently showed significance were conductivity in water quality group, forest area in the land coverage. Conductivity showed different relationship patterns, mostly as expected. Compared with land coverage, the area of urbanized, wetland, open land and water was positively related, while agricultural and forest area was negatively correlated. Other water quality parameters showed some significant relationship, for example, alkalinity, water temperature, and DO %saturation.

The HIS score did not have significant relationship with water quality but two land coverage types such as urbanized and forest area had significance ($p < 0.05$, $n = 27$). The other types of land coverage data neither showed significance, nor high correlation coefficients. With water quality parameters, even though no significant cases were investigated, the values of coefficients were relatively higher than comparison with land coverage.

The results of HIS application to Yangsan Stream presented current stream environments (i.e. land use patterns and morphological characteristics) relatively successfully. During the field monitoring, the main causality of the stream environments degradation was construction activity in- and outside of the stream pathway, such as bridge construction or riparian area modification (levee strengthening). This kind of activity was popular especially in the downtown area (i.e. YS12 to YS7). The sites YS10 and YS09 were free from the construction, so that the index scores were over 30 (level B), but the remaining sites where levee modification (YS12 and YS11) and bridge construction (YS08) occurred were determined as level C and D, respectively. Especially YS08 site was almost completely disturbed by the tentative road creation toward the center waterway for the truck entering. In contrast, the headwater area where Tongdo Temple is located was well preserved and the HIS resulted in level A. Between the two sites (i.e. YS27 and YS26), the latter site obtained higher score, because temple buildings were located within the farthest site area (YS27). The slightly high % distribution of urbanized land coverage indicates this circumstance.

The Yangsan Stream is known as a representative urbanized stream ecosystem in the Nakdong River basin. Complete monitoring from the lowest to the highest segment of the stream revealed that diverse spectrum of riparian characteristics resides in this stream ecosystem. As shown in previous research (e.g. Park *et al*., 1999), the urbanization of the drainage area was the most important factor to the stream environments. The urbanized area in the land coverage encompasses industrial as well as residential area, and this information was well reflected in the HIS scoring at the sites in the downtown reach. Correlation analysis also presented this relationship. The expansion of industrialized area in this basin was recognized as the primary factor for the stream ecosystem, including water quality deterioration (Chung *et al*., 1992; Kim *et al*., 1992), therefore, it is important to control and manage the land use pattern outside the stream pathway in order to increase stream health.

Water quality and the HIS scores for Yangsan Stream did not show significant relationships in this study. Since the sampling program took one week, most of the water quality variables exhibited less fluctuation, and this was the reason why no significant correlation could be obtained. In other words, the high sensitivity of the variables to the temporal scale would be the reason. For example, conductivity and alkalinity, which are not relatively sensitive to temporal scale, exhibited slightly higher levels of correlation. Those parameters showed a clear and significant relationship with land coverage, especially the expansion of urbanized area, which was related to the increase in conductivity. Therefore, it can be thought that the utility of water quality for the relationship discovery with riparian characteristics (either, land coverage or stream naturalness) would be possible when pollution-type water quality parameters were used. From National Institute of Environmental Research (2008), correlation between the HIS scores and water quality was greater in comparison with nutrients such as nitrogen and phosphorus which were significant.

Recent developments in advanced monitoring devices (e.g. satellite imagery, telemetry, high resolution measurements) enable us to collect numerous data across a wide spectrum (Chon *et al*., 1996; Jeong *et al*., 2006). Land coverage data is one of those data types, and is popularly utilized in diffferent subject areas, such as hydrology (Poff *et al*., 2006), benthic invertebrates and their habitats (Sandin, 2009), impact on physical habitat (Pedersen, 2003), and riparian characteristics (National Institute of Environmental Research, 2008). Distribution of biological water quality indices (i.e. benthic algae, macroinvertebrates, etc) were analyzed successfully with respect to land coverage distribution patterns (Korea Environment Institute, 2008), which implies the utility of land cover information for the stream modification and habitat qualification.

The correlation between land coverage and the HIS score implies further ensemble utility of geographical information and stream monitoring results, in developing explanatory models for the current status of stream characteristics. It is possible to develop models using either statistical methods or machine learning algorithms (in other words, Ecological Informatics) which are flexible in model structure determination, compared with deterministic models such as differential equations. Using land coverage information as input data in the model can result in the prediction of the HIS scores, and the prediction and sensitivity analysis results of the model may reveal the relationship between geographical characteristics and the current stream health. The model may allow us to provide management strategy for the streams and rivers health. Furthermore, it is possible to build remote sensing mechanism when the background information and relationship between geographical and national stream health data is available.

Finally, when biological information, such as quantified distribution information of bacteria, plankton, benthic diatoms, macroinvertebrates, fish, and vegetation is available, a more accurate generalization regarding ecosystem health is possible. Biological data, such as listed above are mandatory for the exact characterization of stream health which requires a description of the functional and structural mechanisms within a stream ecosystem. The aforementioned environmental generalization model results can therefore be compared either with the biological information or the model can directly use the biological characteristics. This process can provide important and useful information for the decision makers or ecosystem scientists who are focused on increasing the effectiveness of their work in a larger scope.

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