# The Development of New Fish Monitoring Methodology and Its Application for National Stream Health Assessments in Korea

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## Abstract

The objectives of the study were to develop national stream health assessment model (NSHA) using fish assemblages in Korea during 2003- 2005 and apply the NSHA model to 80 stream and rivers of national major watersheds for the model tests. The NSHA model was based on the metric index of biological integrity (IBI), which was established as a Rapid Bioassessment Protocol (RBP) in the US EPA. For the national model developments, regional trophic guilds and tolerance guilds were analyzed in the four major watersheds in Korea and 39 national reference streams were selected for developments of the maxim species richness line (MSRL). Also, metric numbers and metric attributes of the NSHA were modified and corrected for the regional applications along with establishments of the scoring criteria. In the initial stage we selected 10 metric model and corrected as 8-metric models as a cost-effective strategy. Also, we tested the fitting of the model on the national ecosystems in the relations with habitat health, based on Qualitative Habitat Evaluation Index (QHEI) and conventional water quality criteria. We identified impaired vs. healthy systems by the national biological criteria in nationwide streams and rivers in Korea. The new national biological monitoring methodology would be used as a key tool for ecological restorations and species conservations in Korean aquatic ecosystems.

Keywords: fish monitoring, bioassessment, biological integrity, stream health

## Introduction

Recently, effective management strategies for aquatic ecosystems are developing in many developed countries (Barbour et al., 1999) and the paradigm is changing from the chemical-based to biological approach (Davis and Simon, 1995). During the last several decades, stream water quality has been frequently evaluated by chemical monitoring such as nutrients, biochemical oxygen demand, and hazard chemicals. However, health assessments of aquatic ecosystems, based on various types of aquatic taxa, have been a hot central issue for effective water quality monitoring and this approach has been considered as a surrogate for achieving the goal of ecological integrity in aquatic ecosystems (Karr and Chu, 2000). In fact, Judy et al. (1984) pointed out that simple chemical measurements may not detect an integrative health condition of water environments due to dynamic spatial and temporal variations as well as various habitat degradations (channel modifications) and modified hydrological regime. This fact is supported by various quantitative habitat evaluations (Terrell et al., 1982) and instream flow incremental methodology (Stalnaker, 1982).

Multi-metric models, based on various biological indicators and physical habitats, have been widely applied for evaluations of integrative ecological health in aquatic ecosystems. One of them is a concept of "index of biological integrity (IBI) using fish assemblages and this concept was originally introduced by Karr (1981) for evaluations of water environment reflecting physical habitat, chemical, and biological conditions in small mid-western streams, USA. Since then, 35 states in the USA applied the IBI to wadable streams and rivers (Karr and Dionne 1991) and many other countries. The reason why the IBI is applied to world-wide is due to cost-effective, quantitative, and multi-metric approach (Ohio EPA 1987, Karr and Dionne 1991, Barbour et al. 1999 Karr and Chu 1999) that evaluates various aspects of fish community structures and functions in a specific region. In this study, we developed national stream health assessment (NSHA) model using fish assemblages, and applied to various streams and rivers in Korean watersheds. Also, we compared the model values to conventional water quality (such as BOD) and physical habitat index.

## Material and Methods

Field survey was conducted in 80 temperate stream and river locations during April - June 2005 and fish sampling followed after the wading method (Ohio EPA, 1989). The sampling locations were same as the chemical monitoring sites designated by the government. At the all sites, fish collections were conducted according to the method of the catch per unit of effort (CPUE; Ohio EPA 1989); all habitat types including riffle, run, pool were sampled for a distance of 200 m during 60 minutes. Chemical data such as conductivity, BOD, and TP were obtained from the Ministry of Environment, Korea. Also, fish samples were collected from 39 reference streams and river sites in the Korean major watershed during 2003 - 2005 to derive maximum species-richness lines against the stream order. In selecting the regional reference sites, we followed the approach of Hughes (1995).

For the ecological stream health assessments, eight - ten metric model system was determined and the model based on the 3 major attributes of species richness, trophic and tolerance guild analysis, and individual health (Barbour et al., 1999). National ecological stream health, based on ten-metric models, was initially categorized as five integrity classes of excellent, good, fair, poor, very poor, and worst conditions. We also analyzed the habitat quality, based on the Qualitative Habitat Evaluation Index (QHEI; Plafkin et al., 1989). Seven habitat parameters were selected for the assessment of QHEI, based on the references widely used (U.S. EPA, 1983). The physical habitat health conditions of the habitat were categorized as 4 ranks of "comparable to reference", "support", "partially support" and "non-support".

## Results and Discussions

Preliminary metrics of NSHA model, based on the Index of Biological Integrity (IBI), were composed of three components of species compositions ($M_1$: number of Korean native species, $M_2$: Number of riffle benthic species, $M_3$:Number of sensitive species, $M_4$:Number of tolerant species), trophic compositions ($M_5$: % omnivores, $M_6$: % insectivores, $M_7$: % carnivores) and fish abundance and individual health ($M_8$: total number of native fish, $M_9$: % exotic species, $M_{10}$: fish anormalities). In the mean time, metrics of $M_7$ and $M_9$ were removed from the analysis for 8-metric models.

The values of NSHA model averaged 16.7±9.9 (n=36) in Han-River, 21.0±9.0 (n=40) in Geum-River, 20.6±8.7 (n = 40) in YeongSan/SumJin-River, and 18.4±6.6 (n=36) in Nakdong-River watersheds (Fig. 1).

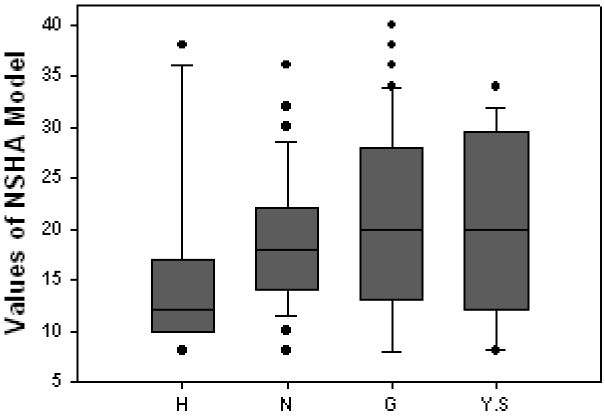

Figure 1. Values of national stream health assessment (NSHA) model, based on the IBI, in the four Korean major watersheds (H = Han-River, N = Nakdong-River, G = Geam River, Y.S. = YeongSan/SumJin River).

The overall values of NSHA, 152 observations of Korean stream and rivers, averaged 19.3 ± 8.7 (n = 172). Thus, the ecological health in Korean watershed was identified as a "*good condition" according to the modified criteria of Karr (1981) and US EPA (1993), but there were large spatial variation depending on the locations and seasons sampled. Pearson's correlation analysis showed that values of NSHA model, based on IBI, were not correlated ($p > 0.05$) with BOD, COD, TP, and TSS. However, when we removed the data during the high-flow (ex, IBI values of > 35 when BOD were > 2.7 $mgL^{-1}$), IBI values had high negative correlations ($r = - 0.890$, $p < 0.05$) with BOD values. Also, TP, COD and TSS had strong correlations with IBI when the data were removed from the analysis.

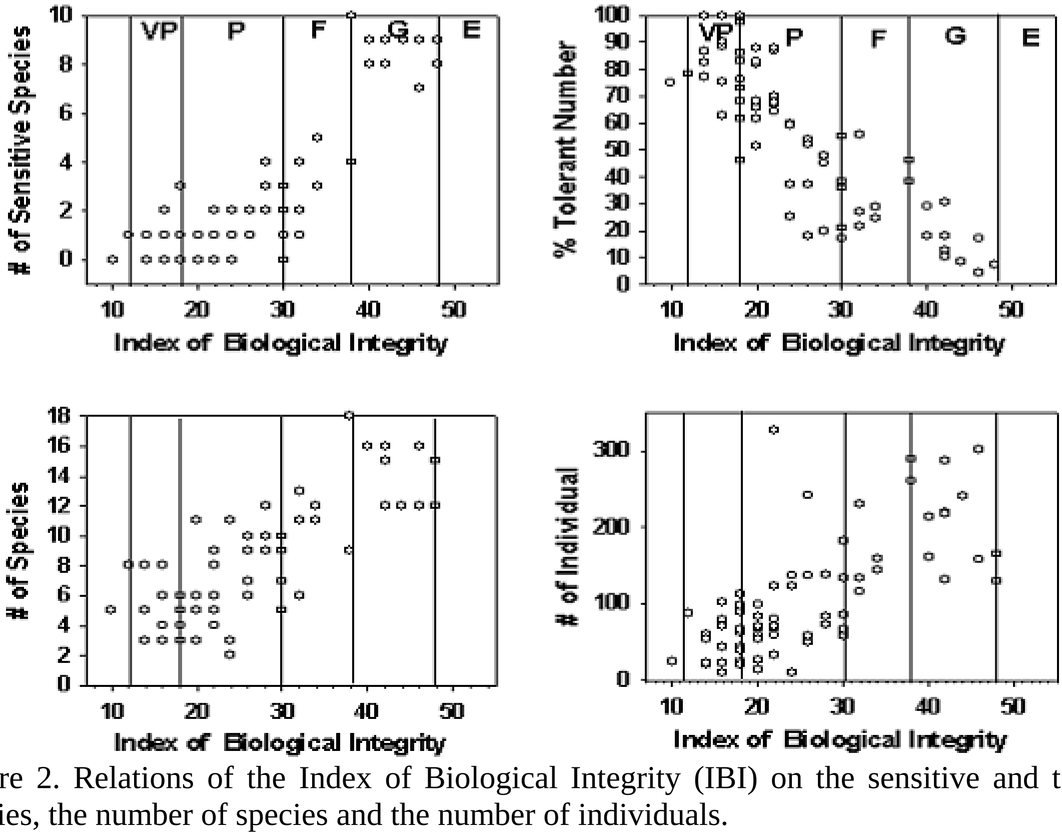

Figure 2. Relations of the Index of Biological Integrity (IBI) on the sensitive and tolerant species, the number of species and the number of individuals.

The index of biological integrity (IBI) also had strong correlations with indicator species (Fig. 2); the abundance of sensitive species increased with high values of IBI, while percent tolerant species decreased with high IBI values. Similar pattern on IBI was shown in the number of individual and the number of species, as shown in the sensitive species. These results indicate that high nutrient enrichment or organic pollution resulted in reduced the model values and this condition modified the relative proportions of ecological indicator species (sensitive vs. tolerant species).

As shown in Fig. 3, values of IBI had high variations when the BOD values were low (1 - 2 mg $L^{-1}$), and the values had low variations when the BOD values were high (4 - 5 mg $L^{-1}$). In other words, when water quality, based on BOD, was good (1 - 2 mg $L^{-1}$), the stream health was judged from 1st rank (excellent condition) to 4the rank (poor condition), indicating a high variation. In contrast, when the water quality was bad (4 - 5 mg $L^{-1}$), IBI was judged as poor - very poor conditions, indicating that the stream health, based on IBI, reflects directly the organic matter pollutions.

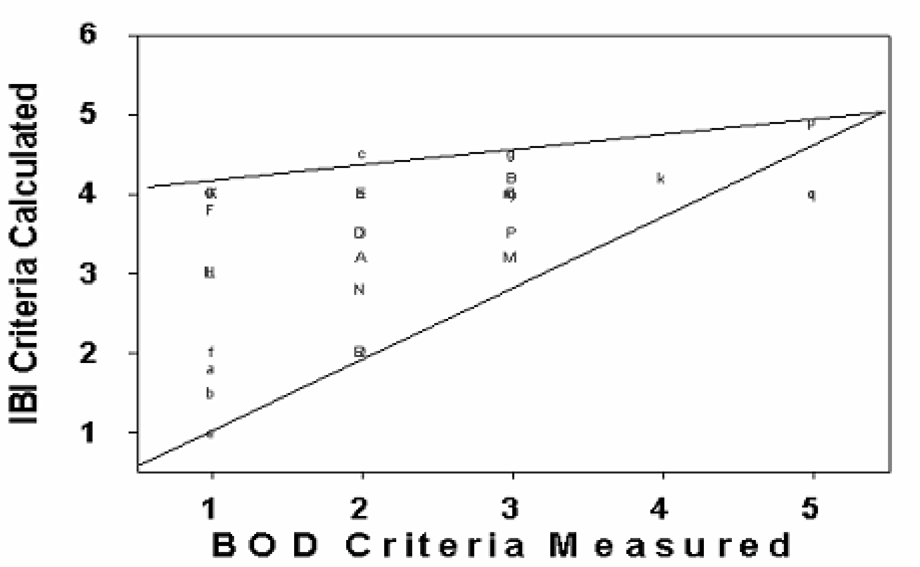

Figure 3. Relations of the criteria IBI calculated vs. BOD criteria measured. The alphabets indicate the streams sampled.

Also, case study in the SumJin / YoungSan Rivers showed that when the BOD values were > 2.5 mg $L^{-1}$, IBIF values (Index of Biological Integrity using Fish) were low, even if the QHEI values were > 50. In contrast, when the BOD values were < 2.0 mg $L^{-1}$, IBIF values had linear functional relations with QHEI. These outcomes indicate that when the chemical water quality is good, the health conditions in the streams and rivers are directly determined by the habitat health. Overall, our results suggest that the ecological stream health in this study was due to combined effects of chemical degradations and habitat degradations. Especially, when the chemical water quality was very good (< 2.0 mg $L^{-1}$ as BOD), still the ecological health showed large variation, so that simple chemical measurements may not detect actual conditions of the ecological health.

This assessment could diagnose the currents health conditions in Korean watershed, so this new monitoring approach may be used as an important management tool for efficient ecosystem managements and restorations.

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## References (Selected)

Barbour, M.T; Gerritsen, J., Snyder, B.D, and Stribling, J.B. (1999). Rapid bioassessment protocols for use in streams and wadable rivers: periphyton, benthic macroinvertebrates and fish. 2nd Eds. EPA 841-B-99-002. Washington, D.C., USA.

Judy, R.D., Seeley, Jr. P.N., Murray, T.M., Svirsky, S.C., Whitworth, M.R., and Ischinger, L.S. (1984). *National Fisheries Survey*. Vol. 1: Technical Report: initial findings. United States Fish and Wildlife Service. FWS/OBS-84/06.

Karr, J.R. (1981). Assessment of biotic integrity using fish communities. *Fishierie*s, **6**, 21-27.

Ohio EPA. (1987). Biological criteria for the protection of aquatic life. Vol.II, Users manual for biological field assessment of Ohio surface waters. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus. OH, USA.

Plafkin, J.L., Barbour, M.T., Porter, K.D., Gross, S.K., and Hughes, R.M. (1989). Rapid assessment protocols for use in streams and rivers:benthic macroinvertebrats and fish. EPA/444/4-89-001, Washington DC, USA.