New Classification Criteria and Database Code of Water Environment for Nature-Friendly River Work and Integrated Management of Watershed

자연친화적 하천사업 및 통합적 유역 관리를 위한 새로운 수환경 분류법 및 자료관리 프로그램의 개발

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Abstract

Nature-friendly river project has became common practice in Japan. In order to make it available for the conservation and rehabilitation of desirable water environment, water criteria for water environmental assessment must be established. Especially, the criteria estimating the effects on ecosystem in and around river should be constructed. In this paper, classification method for water quality has been developed using biological indices and applied to observed data in Honmyo River, Nagasaki, Japan. Modified PI method (BI') has been suggested and those of three most abundant species resulted effective estimate for an overall water quality with comparatively simple procedure. Extensive database management code was prepared for the comprehensive ecological monitoring of river basin, which includes various biota. That system enables easy access of all the ecological data for a dissemination of a sound and sustainable water environment. The result of this study could improve knowledge base, serve making consensus for citizens, and help river management plans. In Japan, citizen's realization and action are the most critical factor for nature-friendly river restoration project.

일본에서는 자연친화형 하천사업을 많이 시행하고 있다. 바람직한 수환경을 보전하고 복원하기 위해서는 하천내외의 생태계에 대한 수질기준을 정립하여야 한다. 본 논문에서는 생물학적 지표를 사용한 수질 분류 방법을 개발하여 나가사키현의 혼묘하천에 대하여 적용하였다. 이러한 수질 분류를 위하여, 수정된 오염물 지표 분류법을 제안하였다. 비교적 단순한 방법이지만, 가장 많은 종에 대한 3가지 지표만으로 수질을 효과적으로 평가할 수 있었다. 또한, 하천유역의 통합관리를 위하여 다양한 생태계 자료를 포함하는 종합적인 자료관리시스템을 개발하였다. 본 시스템을 사용하여 건전한 수환경을 보전하기 위한 각종 생태계 자료를 쉽게 취득할 수 있다. 본 연구의 결과를 사용하여 수질자료를 개선하고, 시민들의 의식을 고양하며, 하천관리계획을 세울 수 있을 것이다. 일본에서는, 자연친화적 하천복원사업에 있어서 시민들의 의식 및 행동이 가장 중요한 요소이다.

key words: nature-friendly river work, monitoring system, water quality, Biological Index

Ⅰ. Introduction

As Japan is located on subtropical area, the region has been suffering from heavy rainfall recurrently. Thus, flood control has been major issue for river management from an ancient era.

Japanese River Act has newly revised in 1997. This is the second revision since its first establishment in 1896, following to those in 1964. One of the main themes in that Act is the emphasis of environmental management. About twenty years ago [Noguchi, 1993], river works were popular to introduce *amenity* to local citizens, such as a construction of park on a water front or *river front space*. Construction works of habitat for fishes, fireflies, and other biota were also started. However, it is recently that biotope, ecotone, and other terms are frequently heard when discussing river management.

Nowadays, nature-friendly river work has gradually become well-known by Japanese. Its main purpose is to create the sound and sustainable water environment based on ecosystem. For attaining this final goal, river should be managed through an appropriate manner, considering local history and natural feature. In this regard, many river restoration works have been introduced and/or under construction. However, in practice, there is very little qualitative information available for river restoration work. Thus, it becomes important to discuss that how we can appropriately estimate the impacts on water environment of the river restoration works, and how we should effectively disseminate knowledge of desirable water environment, strategies for a final goal, and so on.

In order to carry out the above-mentioned matters, extensive field survey has been carried out in Honmyo river which is one of the A-class rivers in Japan. As this river flows into the Isahaya Bay with sea-dyke and reclamation pond, unsuitable river management could induce the deterioration of water quality such as eutrophication. Many indices of water quality have been examined using the Index of Biological Integrity (IBI) for this study. Water environment has been diagnosed using biological indices. Water quality management could be effe ctively implemented by installing a comprehensive database system.

II. Diagnosis of Water Quality Using the Biological Indices

Species in aquatic system changes in accordance to the quality of environment. Namely, pollution intolerant flora and fauna appear in clear water, and vice versa. In this regard, the saprobic theory has been established based on aquatic benthos, which categorizes water into four major ranks; (1) oligosaprobic (os; unpolluted), (2) β-mesosaprobic (β-m; slightly polluted), (3) α-mesosaprobic (α-m; polluted), and (4) polysaprobic (ps; heavily polluted). Here, dominant species method, Biotic Index method (BI method, or Beck-Tsuda method), and Pollution Index method (PI method, or Pantle-Buck method) are well known as the classification of water quality [Tsuda and Morishita, 1974]. These methods have elatively simple procedure. However, because of their simple structure, results of classification are sometimes not necessarily exact. The first method classifies water quality using one species only, the second one sorts by accounting the Biotic Index (BI) based on number of species. On the other hand, the third one carries out classification procedure based on both the numbers of species and individuals. Therefore, the last one seems to be better than the others. Only this parameter is for pollution of water, so BI′ has been defined as a parameter of purification of water using the following equation.

$$BI' = \frac{\sum (S' \cdot h)}{\sum h} \quad (1)$$

Table 1 Relation between BI, BI′ and rank of water quality

BI	BI′	Rank of water quality
20 and over	4.0 – 3.25	Oligosaprobic
11 – 19	3.25 – 2.5	β-mesosaprobic
6 – 10	2.5 – 1.75	α-mesosaprobic
0 – 5	1.75 – 1.0	Polysaprobic

Where, h is the number of individuals and S′is the index of purification. Index, S′ is evaluated as 4 for os, 3 for β-m, 2 for α-m, and 1 for ps. Calculated BI′ can be estimated using Table 1.

In general, taxa richness or degree of biological diversity increases in clear water, so appropriate indices should be defined for its evaluation, such as, Shannon-Weaver function and Index of Biological Integrity (IBI). The former (H′) can be estimated by the following equation.

$$H' = -\sum_{i=1}^{s} \left({n_i}/{N} \right) \log \left({n_i}/{N} \right) \quad (2)$$

Where, s is the number of species, N is the total number of individuals, and n_i, is the number of i^{th} individual.

On the other hand, concept of IBI was introduced in the latter part of 1980′s in U.S.A.

[Morishita, 1996]. This index shows a degree of integrity in streams using many biological indices as metrics. If we consider that water has been polluted mainly by artificial influence, species which is either tolerant or intolerant to pollution conditions can be analyzed using this metrics. In order to make the IBI available for the judgement of water quality, Morishita carried out the detailed investigation, and derived the criteria of judgement for water environment (see Table 2) as scoring index for each biological characteristic [Morishita, 1996].

Table 2 Scoring criteria of biological characteristics in aquatic ecosystem

Biological characteristics	Score		
	1	3	5
1. Total taxa richness	0-13	14-26	>27
2. Mayfly taxa richness	0-4	5-8	>9
3. Caddisfly taxa richness	0-3	4-6	>7
4. Clinger taxa richness	0-8	9-16	>17
5. Intolerant taxa richness	0-9	10-17	>18
6. tolerant organisms (%)	>16	16>X>4	<4
7. legless organisms (%)	>40	40>X>4	<4
8. mud burrowers (%)	>38	38>X>19	<19
9. oligochaeta (%)	>20	20>X>6	<6
10. 3 most abundant taxa (%)	>82	82>X>42	<42

Ⅲ. Outline of the Honmyo River and Its Basin

Field observation of aquatic ecosystem has been carried out in the Honmyo River since 1990. [Noguchi and others, 1995, 1998]. This river is small sized urban river in A-class water quality with 21km long and about 87 km^2.of river basin. Because the project of sea-dyke and reclamation in Isahaya Bay is now under construction at the downstream of the Honmyo River, the importance of river management s hould be emphasized. In this project, a regulation pond is also planned, aiming the disaster prevention as well as creation of new land for agriculture. Because of the possible degradation of water quality in the regulation pond, the other studies are also carrying out to investigate the effects on water environment by construction of sea dyke [Noguchi and others, 1994; Noguchi and Nishida, 1997]. Elaborate strategy for prevention of water pollution in the pond should be provided.

For accomplishment of desirable water environment including the above-mentioned area, lots of efforts should be devoted for the integrated management of river and its basin, for example, suppression of untreated runoff of pollution into the water, execution of river restoration work, and so on. Following to the prescribed history of river management, river restoration work has been carried out, mainly from the end of 1980's. Situation is almost the same, also in the Honmyo River. In Japan, existence of traditional river works called the willow tree work, wooden frame work, and others, is well known. Photos 1 to 3 show a historical change of the Honmyo River at *Shimen* Bridge, where artificial impoundment of water called "*Wande*" has been constructed since 1990. As described above section, similar river works have

Photo 1 Before river works on Aug. 1990

Photo 2 Under river works on Apr. 1992

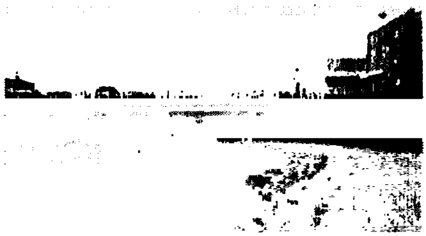
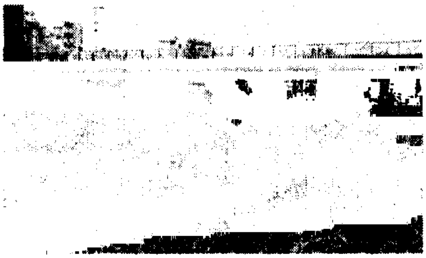


Photo 3 After river works on Sep. 1996



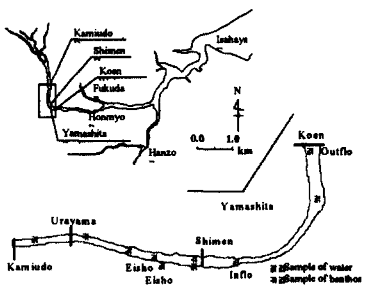


Figure 1 Schematic view of study area

been constructed over the numerous Japanese rivers. At the same time, their influences on the water environment were discussed in the various points of view.

Ⅳ. Overall Estimation of Water Quality in the Honmyo River

Extensive field observation has been carried out to estimate water environment in the Honmyo River. Biological indices have been compared with one another for an overall estimation of water quality. In Figure 2, spatial variations of water quality in a longitudinal direction are shown. For biological estimation, three methods are used such as the dominant specie method, and BI and BI′ methods. In this figure, results are shown separately both on the left and right sides of stream. It becomes clear that water quality of the Honmyo River can be judged as slightly polluted, that is β-m or α-m. Difference between each result is not so large for categorizing the rank of water quality, but result derived by the dominant species method sometimes differs from the others, such as those observed at fall of 1996. This is due to the fact that water quality is judged based upon only one species. Thus, the method of three most abundant species are proposed to be used instead of the dominant specie method (Figure 3). It becomes apparent that the above-mentioned matter is proven.

In Figure 4, longitudinal distribution of biological diversity calculated by the Shannon-Weaver function has been compared with those derived by BI′ method. Both results are similar to one another for almost all cases. On the other hand, score of diagnosis in each observatory station has been counted in this reach using the Index of Biological Integrity, that is IBI (Table 2). Comparative result of BI′ and IBI has been illustrated in Figure 5, which shows a remarkable discrepancy between both results. In spite of this result, water quality in Honmyo River seems to be slightly polluted as described before. Further investigation of an appropriate number of metrics and name of species in IBI needs to be carried out.

V. Monitoring and Dissemination of River Environment

Consciousness of citizens for desirable water environment becomes necessary for attaining the final goal. Monitoring of river environment and dissemination of its information are inevitable for this purpose. Rapid development of information management system makes them possible, and citizens who need information of local river can easily access the system. In Japan, census for ecosystem such as plants, birds, insects, aquatic benthos, and others has been implemented for a river front sponsored by the Ministry of Construction, and their results have been stored in a CD-ROM [Technology Research Center for River Front Development, 1996]. Before an establishment of the Foundation of River and Basin Integrated Communications (FRICS), it was difficult to get the up-to-dated information about rainfall-runoff. However, recently, acquisition of these data becomes possible on a real time basis [Foundation of River & Basin Integrated Communications, Japan, 1998]. The dissemination of available information in Internet system plays an important role for a sound and sustainable water environment. Figure 6 shows one example of display of database for dissemination of water environment to local citizens in the Honmyo River. This system suggests rank of water quality classified by biological indices from the input of obs erved results. In order to make this attractive for all persons, further modification becomes necessary. For the system, all samples are sorted and appraised using biological index. This data processing makes the system more accessible to non-biologists who need the information.

VI. Conclusions

Effective biological classification method has been suggested to evaluate overall water environment and applied to river restoration work of Honmyo River. Some comments are with respect to the sound and sustainable water environment in and around river. The importance of effective monitoring is stressed, including appropriate dissemination strategy for the creation of desirable water environment. This study can be summarized as follows:

1) Diagnosis using Biological Index is useful to estimate water environment, and to monitor water quality for river restoration work.

Table3. Score of diagnosis using IBI-J

Metric	Score													
	Left Riparian							Right Riparian						
Oct-94	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.1	St.2	St.3	St.4	St.5	St.6	St.7
Total taxa richness		1	1	1	1	1	1		1	1	1	1	1	1
Intolerant taxa richness		1	1	1	1	1	1		1	1	1	1	1	1
percentage of tolerant organisms (%)		1	1	1	1	1	1		1	1	1	1	1	1
percentage of legless organisms (%)		3	3	1	1	3	1		1	1	3	1	1	1
percentage of mud burrowers (%)		5	5	5	5	5	1		5	5	5	5	5	1
percentage of oligochaeta (%)		5	5	5	5	5	1		5	5	5	5	5	1
percentage of 3 most abundant taxa (%)		1	1	1	1	1	1		1	1	1	1	1	1
Total score		17	17	15	15	17	7		15	15	17	15	15	7
	Left Riparian							Right Riparian						
Jan-95	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.1	St.2	St.3	St.4	St.5	St.6	St.7
Total taxa richness	1	1	1		1	1	1	1	1	1		1	1	1
Intolerant taxa richness	1	1	1		1	1	1	1	1	1		1	1	1
percentage of tolerant organisms (%)	1	1	1		1	1	1	1	1	1		1	1	1
percentage of legless organisms (%)	3	1	1		1	1	1	3	1	1		3	1	1
percentage of mud burrowers (%)	5	1	3		1	1	1	3	5	5		5	5	1
percentage of oligochaeta (%)	5	5	5		5	5	1	5	5	5		5	5	1
percentage of 3 most abundant taxa (%)	1	3	3		3	1	1	1	1	3		3	1	1
Total score	17	13	15		13	11	7	15	15	17		19	15	7
	Left Riparian							Right Riparian						
Aug-95	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.1	St.2	St.3	St.4	St.5	St.6	St.7
Total taxa richness	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Intolerant taxa richness	1	1	1	1	1	1	1	1	1	1	1	1	1	1
percentage of tolerant organisms (%)	1	1	1	1	1	1	1	1	1	1	1	1	1	1
percentage of legless organisms (%)	1	3	1	1	1	1	1	1	1	1	1	1	3	1
percentage of mud burrowers (%)	1	3	5	1	1	1	1	3	1	1	1	3	3	1
percentage of oligochaeta (%)	5	5	5	5	5	5	1	5	5	5	5	5	5	1
percentage of 3 most abundant taxa (%)	1	1	1	3	3	1	1	3	3	1	3	1	1	1
Total score	11	15	15	13	13	11	7	15	13	11	13	13	15	7
	Left Riparian							Right Riparian						
Nov-96	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.1	St.2	St.3	St.4	St.5	St.6	St.7
Total taxa richness			1	1	1	1				1	1	1	1	
Intolerant taxa richness			1	1	1	1				1	1	1	1	
percentage of tolerant organisms (%)			1	1	1	1				1	1	1	1	
percentage of legless organisms (%)			1	1	1	1				1	3	1	1	
percentage of mud burrowers (%)			1	3	1	3				1	5	1	3	
percentage of oligochaeta (%)			1	3	1	5				1	5	3	3	
percentage of 3 most abundant taxa (%)			3	3	3	3				3	3	3	3	
Total score			9	13	9	15				9	19	11	13	

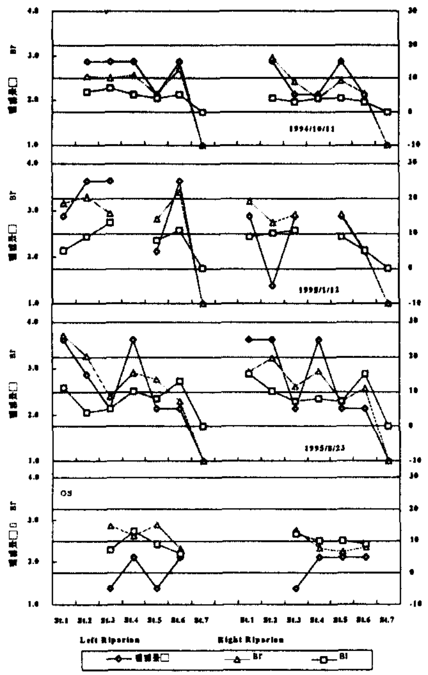


Figure2. Water quality classification in dominant specie method , BI and BI '.

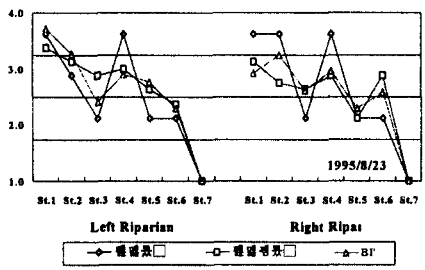


Figure3. Water quality classification in dominant specie, three most abundant species and BI ' methods .

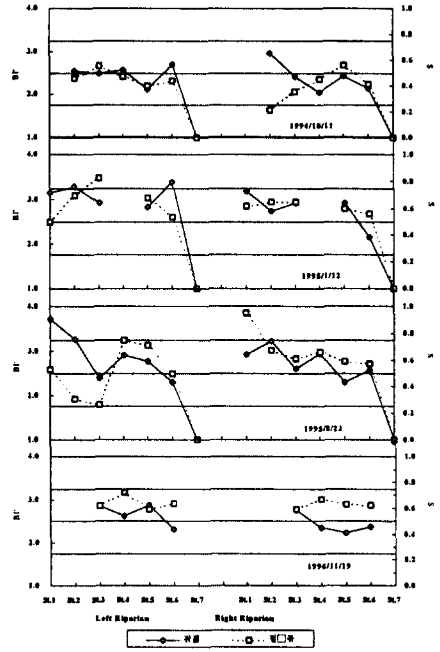


Figure4. Water quality classification in BI ' and the Shannon -Weaver function

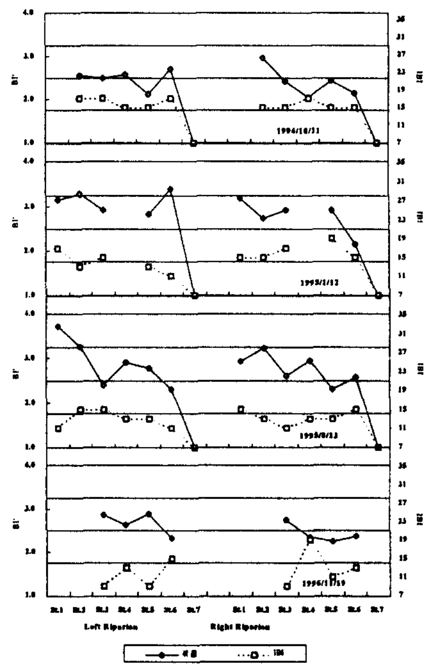


Figure5. Water quality classification using BI ' and IBI.

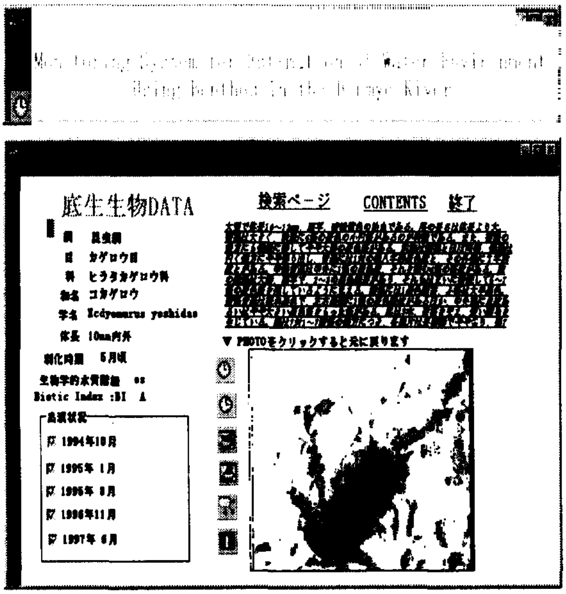


Figure 6 Display of database for dissemination of water environment in the Honmyo River

2) It will be cost-effective and further effects can be expected if associated with chemical ones.
3) River management utilizing these information would improve the knowledge base, serves making consensus for citizens, and helps to refine
   the management plans.
4) It should be emphasized that river environment be managed based upon local history, long term planning, and integral conservation of river and its watershed.

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