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Benthic Macroinvertebrates for Uses in Stream Biomonitoring and Restoration

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Abstract

Biomonitoring is the use of biological responses of populations and communities of certain indicator organisms to evaluate mainly anthropogenic environmental changes. Stream ecosystem biomonitoring using benthic macroinvertebrates is reviewed from a historical perspective. Case studies are provided from the biomonitoring and restoration projects in the Han River system: main watercourse of the Han River, Cheonggye-cheon, Jungnang-cheon, Wangsuk-cheon, and Gapyeong-cheon. From the case studies as well as other various biomonitoring projects conducted in Korea, representative benthic macroinvertebrate groups, which are useful for the biomonitoring and restoration programs in Korean streams, are suggested with a list of endangered, rare, and eco-environmentally valuable species of freshwater arthropods.

Keywords: *benthic macroinvertebrates, bioindicators, biomonitoring, ecological engineering, stream biomonitoring, stream restoration*

1. Introduction

The Korean peninsula is located in temperate Northeast Asia. Since most of the peninsula is mountainous, stream systems are well developed, but there are few large freshwater natural lakes and wetlands. Northeast Asia, including the Korean peninsula, has a relatively high degree of biodiversity. There have been, however, increasing concerns on the loss of biodiversity of freshwater benthic macroinvertebrates along with stream environment degradation because natural stream ecosystems in Korea have been greatly changed since the 1960s when the Korean government launched a program for land development (Bae and Lee, 2001).

Major anthropogenic environmental changes in Korean streams can be classified into physical habitat change and chemical water quality change (Table 1). Habitat change includes increase of lentic areas by dam constructions, water level decrease and dried section increase by the development of agricultural, industrial, and drinking water resources, and water course modification (channelization) by urbanization. Water quality change includes eutrophication and increase of toxic chemicals. In addition, general stream ecosystem disturbances by recreational activities have considerably increased recently.

It is widely known that these environmental impacts and changes can be assessed and monitored not only by physical and chemical techniques but also by biological methods. These biological methods, known as biological water quality assessment and biological water quality monitoring, have been largely developed for recent years. Biological monitoring or "bio-monitoring" can be defined as the systematic use of biological responses to evaluate changes in the environment, which are often due to anthropogenic sources, with the intent to use this information in a quality control program (Rosenberg and Resh, 1993). The general terms "water quality monitoring" and "environmental surveillance" include physical and chemical as well as biological monitoring.

Benthic macroinvertebrates refer to the organisms that inhabit the bottom substrates (sediments, debris, logs, macrophytes, filamentous algae, etc.) of freshwater habitats, for at least part of their life cycle (Rosenberg and Resh, 1993). They are generally called as invertebrates observed by naked eyes but often are categorized as those retained by mesh size more than 0.2-0.5 mm. Freshwater arthropods including aquatic insects take amount of about 95% of benthic macroinvertebrates in terms of species richness and individual abundance. Up to date, 536 species of

Table 1. Major Anthropogenic Environmental Changes of Stream Ecosystems in Korea (from Bae and Lee, 2001)

1. Physical habitat changes: - Lentic areas increase by dam construction and reservoir building - Water level decrease and dried section increase by regulation, development of agricultural, industrial, and drinking water resources, etc. - Water courses modification (channelization, diversion, dredging, revetments, overflow weir, etc.) by urbanization.
2. Chemical water quality changes: - Eutrophication by living wastewater, sewage, etc. - Toxic chemicals (heavy metals, pesticides, organic compounds, ammonia, etc.) increase by industrial wastewater, etc.
3. Other changes: - Sedimentation and garbage accumulation by flood - General disturbances increase by recreational activities

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freshwater arthropods, belonging to 112 families, 18 orders, and 3 classes and including 494 species of aquatic insects in 96 families, are known in Korea, although more intensive taxonomic studies, especially on aquatic flies (Diptera), are needed (Bae and Lee, 2001).

The purpose of this paper is to introduce a brief historical background of freshwater biomonitoring using benthic macroinvertebrates and their application to stream restoration and ecological engineering with case studies in Korea.

2. Benthic Macroinvertebrates as Bioindicators

Benthic macroinvertebrates are the most popular and commonly used group of freshwater organisms in assessing water quality. They offer many advantages in biomonitoring although a practice for well-balanced monitoring programs such as quantitative sampling and community analysis is required (Rosenberg and Resh, 1993). First, they are ubiquitous and thus can be affected by environmental perturbations in many different types of aquatic systems. Second, the large number of species involved offers a spectrum of responses to environmental stresses. In Korean streams, benthic macroinvertebrates usually are the major group of organisms in terms of species richness and individual abundance in whole the watercourses from headwaters to river mouths and from clean mountain streams to polluted urban streams. Third, their basically sedentary or benthic habit allows effective spatial analyses of pollutant or disturbance effects. Fourth, they have relatively long life cycles compared to other groups of freshwater organisms, which allows elucidation of temporal changes caused by perturbations. As a result, benthic macroinvertebrates act as continuous bioindicators of the water body they inhabit, enabling both temporal and spatial analyses of various degrees of aquatic environment.

3. Bioindicators and Biotic Indices

Various technical developments have been achieved in the use of benthic macroinvertebrates as advantageous biomonitors in stream ecosystems. In the beginning time, a relatively simple way of biomonitoring such as appearance or disappearance of selected indicator species was used, but biomonitoring programs have been rapidly developed and more sophisticated techniques such as population and community indices have been introduced (Table 2) (Yoon and Bae, 1993). These technical developments are largely due to the developments of quantitative sampling and sample analyses including inexpensive sampling equipments and computer devices, taxonomic and identification references, and supports of ecological and toxicological researches.

Since the mid-nineteenth century, limnologists have been aware that aquatic organisms can be used as environmental indicators since they are exposed to various degrees of environmental degradation for their life span. Kolkwitz and Marsson (1902) firstly introduced four-graded saprobic system in streams using indicator organisms that inhabit typically along the watercourse. Since then, various biological indices have been invented depending on the organisms and analysis methods such as relative purity, saprobic index, saprobic valency, indicative weight, Trent biotic index, score system, Hilsenhoff biotic index, etc. (Rosenberg and Resh, 1993). Sladecek (1973a) divided the saprobic system into eight-graded system using 2000 species of freshwater organisms; Tuffery and Verneaux (1968) invented systems used for running and standing waters. Kothe (1962) developed a species-deficit method, an advanced community analysis method; Wilhm and Dorris (1968) invented a species diversity index which is based on Margalef 's (1958) information theory and Staub *et al*. (1970) adopted it to saprobic system in freshwaters.

Table 2. Classification of Bioindicators and Biological Indices (Modified from Yoon and Bae, 1993)

1. Indicator species -Population index (e.g., relative abundance of indicator species)
2. Indicator community -Community index Unweighted community index (e.g., species diversity index) Weighted community index (e.g., TBS method)

Along with this theoretical development of biological indices, local governments or countries throughout the world have developed their own biological indices based on the native organisms inhabited in the places (Persoone and De Pauw, 1979; Resh *et al*., 1995): United Kingdom (Woodiwiss, 1964, 1978; Sladecek, 1973b), Germany (Knöpp, 1954; Pantle and Buck, 1955; Zelinka and Marvan, 1961), France (Tuffery and Verneaux, 1968), Denmark (Anderson *et al*., 1984), Netherlands (Klapwijk, 1988), Spain (Zamora-Munoz and Alba-Tercedor, 1996), and Australia (Crowns *et al.*, 1997) have developed their own biological indices. In North America, Richardson (1928), Bartsch and Ingram (1959), Hynes (1960), and Gaufin (1973) initiated this research and most states have their own biological indices: Wisconsin (Hilsenhoff, 1977, 1982, 1988), Ohio (Olive and Smith, 1975; Olive, 1976), Kansas (Chutter, 1972), West Virginia (Wojcik and Butler, 1977), and Florida (Barbour *et al.*, 1996). In Japan, Tsuda (1964) developed Beck-Tsuda method and Gose (1978) suggested modified Zelinka-Marvan's (1961) method.

Since 1970s, biological water quality assessments using aquatic insect or benthic macroinvertebrate communities have been popularly introduced to Korean streams (see Yoon and Bae, 1993; Bae, 1996), but most of them are four-graded saprobic system (Staub *et al*., 1970), an unweighted community index, based on species diversity index (Wilhm and Dorris, 1968; Pielou, 1966). On the other hand, other community indices, i.e. weighted community indices, such as Tsuda (1964), Sramek-Husek (1956), Hilsenhoff (1977), Trent biotic index (Woodiwiss, 1978), Biotic score (Chandler, 1970), and Monitoring working party score (Hellawell, 1986) were empirically introduced to Korean streams and a Korean biotic index or Yoon-Kong's Total Biotic Score, a modified Zelinka-Marvan's (1961) method, was invented (Yoon *et al*., 1992a, 1992b, 1992c). This Total Biotic Score method (TBS method) has been modified to a simplified biotic index (Yoon, 1995), which is widely used in Korean streams these days.

4. Case Studies

Freshwater benthic macroinvertebrate communities in Korean streams have been affected by the anthropogenic environmental

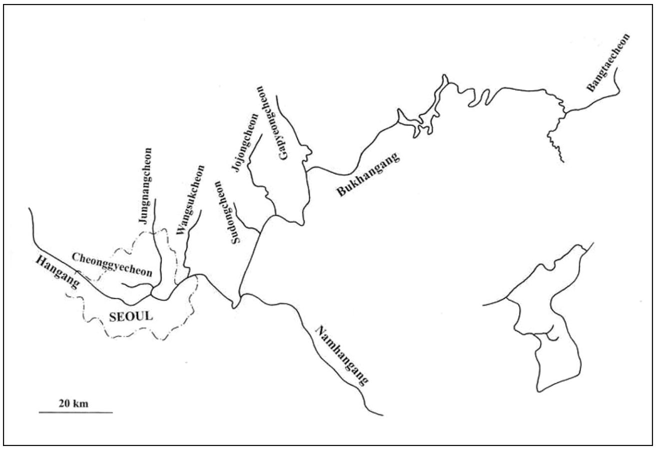


Fig. 1. The Han River System Showing Major Tributary Streams (from Bae and Lee, 2001)

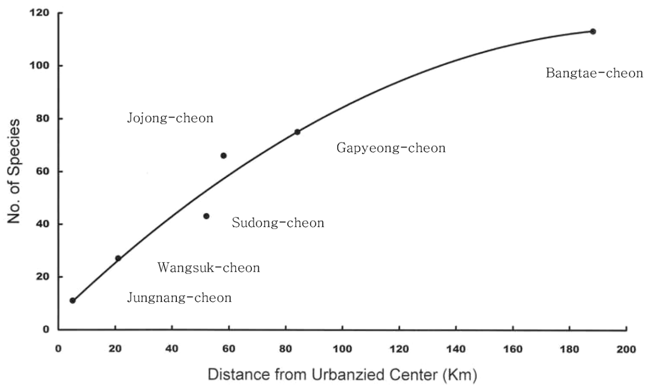


Fig. 2. A Relationship Between Distance from the Center of Urbanization (Seoul) and Number of Aquatic Insect Species in the Tributary Streams of the Han River System (Modified from Bae and Lee, 2001)

changes mentioned above. Particular attention is given to the impact of urbanization since it is regarded as the most significant human impact on Korean streams in recent years. As shown in a long-term biomonitoring study in the Han River system (Fig. 1), one aquatic insect species disappeared for about every 20,000 increase in human population and for about every 2 km decrease in distance to the center of urbanization (Seoul) (Fig. 2).

Biomonitoring programs using benthic macroinvertebrates have been variously applied to the main watercourse and tributary streams of the Han River. The followings are brief introductions to the case studies.

4.1. The Han River

The main watercourse of the Han River has been greatly changed since early 1980s when Seoul city government launched a comprehensive development project on the river. For the first five-year period from 1982 to 1987, the river banks of the watercourse running through Seoul city was almost entirely channelized with cement bricks and the flood plane was cleaned and flattened (Fig. 3E). A long-term biomonitoring of benthic macroinvertebrates well reflects this anthropogenic environmental change as shown in Fig. 4 (Bae and Lee, 2001; SMG, 2002). The species number of major aquatic insect groups has drastically decreased soon after the channelization, but it has recovered although the species composition is different from that of pre-channelized conditions.

4.2. Cheonggye-cheon

Cheonggye-cheon (Cheonggye stream) is a tributary of Jungnang-cheon running through the downtown Seoul city. It is about 10.3 km in length and flows into the lower part of Jungnang-cheon, which empties into the Han River (Fig. 1). About 7.5 km length of the watercourse was covered with cements (culverted) in the 1960s as the city has developed to a megacity (Fig. 3A, B, C). In addition to a function of sewage tunnel, the paved surface of the covered stream section has been used as a traffic road (Fig. 3C). In July 2003, a stream restoration project started and the cement pavement has been uncovered from the stream. According to the restoration project, the instream and riparian areas will eventually be restored as shown in Fig. 3D.

A monitoring project showed that twenty and fourteen species of benthic macroinvertebrates occurred in the uncovered upper and lower sections of the stream, respectively, but only four species were found inside the two sewage tunnels (Table 3) (Bae, 2004). The species found in the upper sections are intolerant species, whereas those in the lower stream sections and inside the tunnels are tolerant species.

After the restoration project, we can predict the species that may colonize to various restored microhabitats in the stream as in Table 4. These colonizers are drawn from previous survey data from the same stream as well as from comprehensive distributional and ecological data from other streams, which have similar habitats. We can also use those benthic macroinvertebrates as target species in the restoration program so as to restore certain habitat conditions preferable to the species. This is the other aspect of biomonitoring that may be applicable to stream restoration.

4.3. Jungnang-cheon

Jungnang-cheon is located in the eastern part of Seoul city (Fig. 1). The stream has been heavily urbanized as the city grows and the water has been getting seriously polluted due to large amount of wastewater drained from the city. In early 1990s, a sewage culvert line was established along the stream bank and the riparian environment has been largely improved. Changes of the species number and composition of benthic macroinvertebrates shown in Fig. 5 well reflect this environment change of the stream condition (SMG-RIPHE, 2001).

4.4. Wangsuk-cheon

Wangsuk-cheon is located close to the border between Seoul city and Gyeonggi-do (Fig. 1). The stream has been greatly affected by the expansion of Seoul city since the 1960s and the stream is on a way of changes from a natural stream to a typically urbanized stream in Korea. Based on a long-term biomonitoring of benthic macroinvertebrates in the stream, we found that one aquatic insect species disappeared about every two years since the 1960s (Yoon *et al*., 1993).

A long-term biomonitoring of benthic macroinvertebrates from a mid-stream section of Naegak area in Wangsuk-cheon indicated that the benthic macroinvertebrate community completely disappeared after a dredging accompanied by the channelization

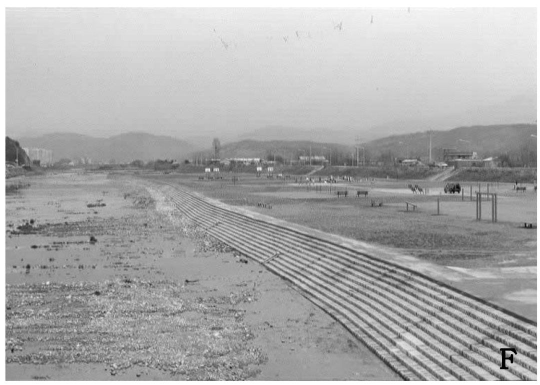
(A) Cheonggye-cheon in Early 1900s

(B) Cheonggye-cheon in 1960s when a Cement Pavement (Culvert) Project was Launched

(C) Cheonggye-cheon in 2003 Showing Motorways on Paved Watercourse

(D) A Computer Graphic of Cheonggye-cheon after Restoration Project

(E) Channelized River Bank of the Han River in Seongdong-gu, Seoul



(F) Channelized Stream Bank of Wangsuk-cheon in Gyeonggi-do

Fig. 3. Photographs of the Han River and Tributary Streams (A-D from a Webpage of Seoul City)

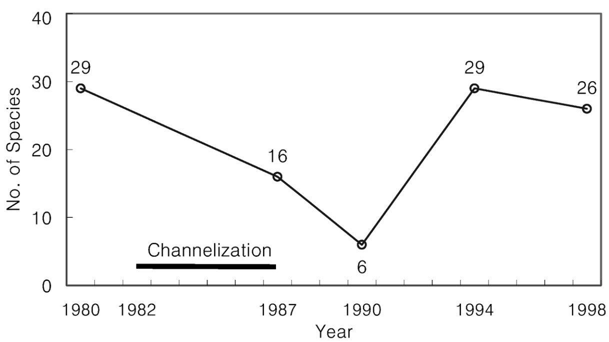


Fig. 4. A Long-term Change of Species Number of Major Aquatic Insect Groups in the Main Stream of the Han River in Seoul, Which has been Influenced by Channelization in the 1980s (Modified from Bae and Lee, 2001)

in 1994 (Fig. 3(F)), but the community has not been recovered until a heavy flood in 1997. The flood event facilitated a habitat alteration that eventually has brought a recovery of the benthic macroinvertebrate community (Fig. 6) (Bae *et al*., 1996). To recover a benthic community after channelization, it took four times longer in urban streams as in cases in Wangsuk-cheon and the Han River (ca. four years in Wangsuk-cheon and ca. 10 years in the main watercourse of the Han River) than in natural streams, but the compositions of the communities were different from those of the pre-channelized communities.

4.5. Gapyeong-cheon

Gapyeong-cheon is located about 60 km northeast Seoul and the stream basin is relatively well-preserved despite of recent

Table 3. Species Number of Benthic Macroinvertebrates from Cheonggye-cheon in 2003 (Modified from Bae, 2004)

	Tributaries of upper stream	Covered area	Groundwater area of lower stream
Ephemeroptera	3	0	0
Plecoptera	2	0	0
Trichoptera	2	0	0
Diptera	7	0	6
Other aquatic insects	3	2	3
Mollusca	0	0	2
Other non-insects	3	2	3
Total species number	20	4	14
Total species number from whole area	30		

Table 4. Prediction of Major Benthic Macroinvertebrate Taxa, which May Colonize after the Restoration Project of Cheonggye-cheon (Modified from Bae, 2004)

Riffle areas (with stone substrate)	baetid mayflies (*Baetis* spp.), heptageniid mayflies (*E. latifolium*), hydropsychid caddiflies (*H. kozhantschikovi*)
Stagnant and streaming areas	some bugs (*G. insularis, H. kolthoffi*), some beetles (*H. striatus*), some mayflies (*Caenis* sp.), some shellfishes (*S. gottschei, S. tegulata*)
Waterweed areas	some dragonflies (*I. asiatica*, *O. speciosum*), some bugs (*D. japonicus*, *R. chinensis*)
Inner substrate	burrowing mayflies (*E. orientalis*, *P. yooni*) chironomid midges (*Chironomus* spp.)

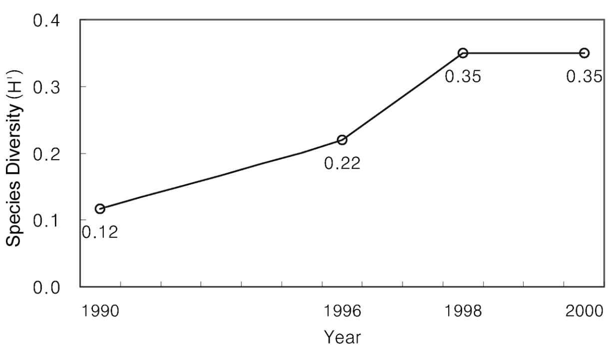


Fig. 5. Changes of Species Diversity of Benthic Macroinvertebrates in Jungnang-cheon from 1990 to 2000 (Modified from SMG-RIPHE, 2001)

anthropogenic influence such as tourism and housing development. The drainage area includes Myeongjisan preserve area but excludes large cities and industrial complexes. A long-term biomonitoring of benthic macroinvertebrates in Gapyeong-cheon with additional data from other surveys in preserved Korean streams led to a list of endangered, rare, and eco-environmentally valuable species of freshwater benthic macroinvertebrates in Korea as in Appendix 1 (Bae and Lee, 2001; Bae *et al*., 2003a).

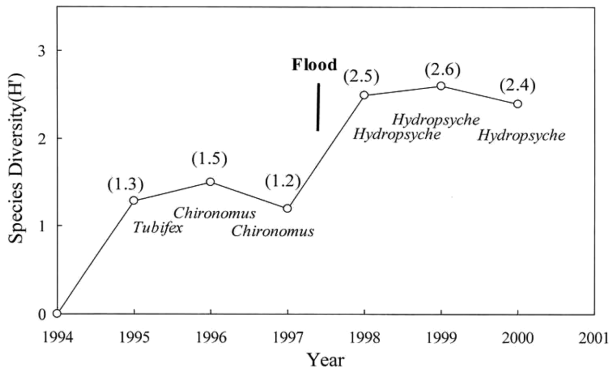


Fig. 6. Changes of Species Diversity and Dominant Species after Channelization in 1994 in Mid-stream Section of Wangsuk-cheon. A Heavy Flood Event in 1997 Facilitated Habitat Alteration and an Eventual Recovery of the Benthic Macro-invertebrate Community (from Bae *et al*., 1996)

Based on this long-term study on benthic macroinvertebrates and their associated habitats in Gapyeong-cheon, an environmental assessment technique (rapid assessment technique for nature quality of stream ecosystems) was also presented (see Bae *et al*., 2003b).

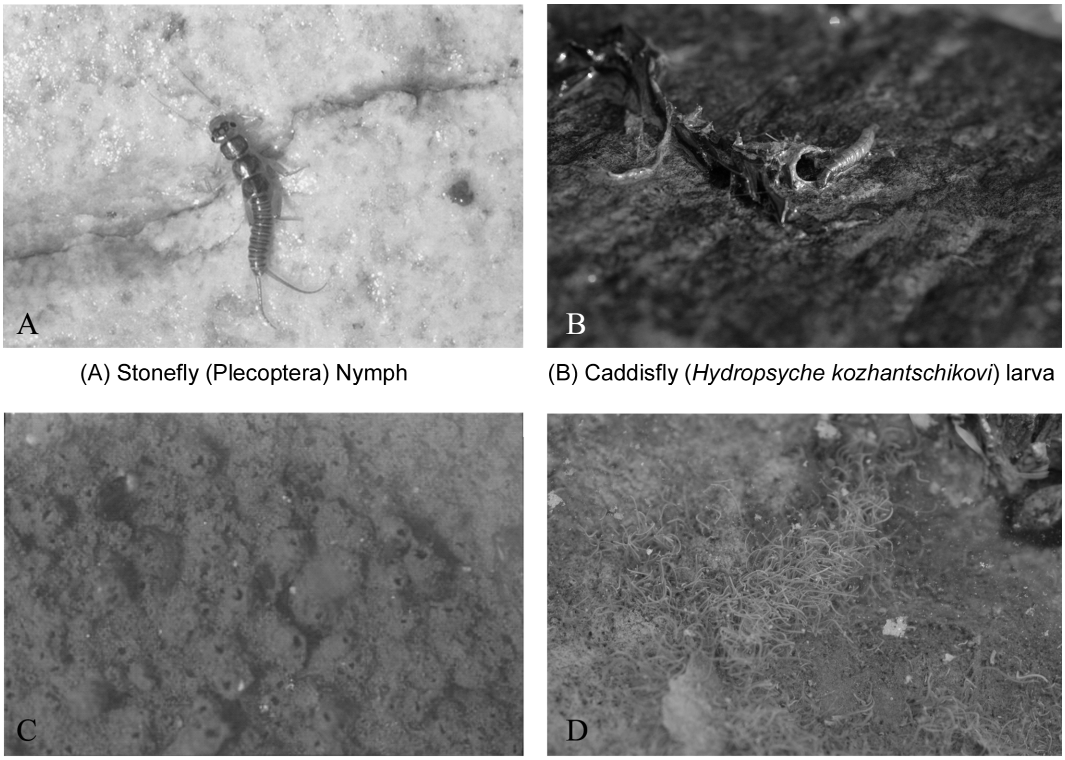
5. Conclusions

As shown above, benthic macroinvertebrates are widely used for the biomonitoring of stream water quality and environment. They are also useful in stream restoration and ecological engineering because they may provide useful information on suitable habitats and other environmental conditions in the restoration practices.

From the above case studies and other various biomonitoring projects (Bae and Lee, 2001), the following benthic macro-invertebrate groups are selected as representative indicator groups in Korean streams in terms of the degree of water quality and habitat degradation (Table 5, Fig. 7): *Drunella* - Plecoptera - *Rhyacophilla* in oligosaprobic, *Hydropsyche kozhantschikovi* - *Uracanthella rufa* - *Epeorus latifolium* in β-mesosaprobic, *Chironomus yoshimatsui* - group in α-mesosaprobic, and Tubificidae in polysaprobic streams.

Table 5. Representative Benthic Macroinvertebrate Taxa in Korean Streams According to Saprobic Value Based on Shannon-Wiener's Species Diversity Index (H') (Modified from Bae and Lee, 2001)

Saprobic values	H'	Representative benthic macroinvertebrate taxa
Oligosaprobic	3.0-4.5	*Drunella*, Plecoptera, *Rhyacophilla*
β-mesosaprobic	2.0-2.9	*Hydropsyche kozhantschikovi*, *Uracanthella rufa*, *Epeorus latifolium*
α-mesosaprobic	1.0-1.9	*Chironomus yoshimatsui* - group
Polysaprobic	0-0.9	Tubificidae



(A) Stonefly (Plecoptera) Nymph

(B) Caddisfly (*Hydropsyche kozhantschikovi*) larva

(C) Chironomid (*Chironomus yoshimatsui*) larvae

(D) Tubificid Earth Worms (Tubificidae sp.)

Fig. 7. Representative Benthic Macroinvertebrate Taxa in Korean Streams According to Saprobic Values (See Table 5)

Acknowledgement

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Appendix 1.

List of endangered, rare, and eco-environmentally valuable species of freshwater arthropods in Korea for uses of streams or wetlands conservation (Three asterisks: highest grade) (from Bae and Lee, 2001).

Taxa	Grade
Class Arachnida	
Order Araneae	
Family Argyronetidae	
1. *Argyroneta aquatica* (Clerck)	***
Class Crustacea	
Order Decapoda	
Family Cambaridae	
2. *Cambaroides dauricus* (Pallas)	**
3. *Cambaroides similis* (Koelbel)	*
Class Insecta	
Order Ephemeroptera	
Family Ameletidae	
4. *Ameletus costalis* (Matsumura)	*
5. *Ameletus montanus* Imanishi	*
Family Baetidae	
6. *Procloeon halla* Bae and Park	*
Family Caenidae	
7. *Brachycercus tubulatus* Tshernova	**
Family Ephemerellidae	
8. *Drunella solida* (Bajkova)	*
9. *Drunella lepnevae* (Tshernova)	*
Family Ephemeridae	
10. *Ephemera separigata* Bae	*
Family Heptageniidae	
11. *Bleptus fasciatus* Eaton	**
12. *Cinygmula grandifolia* Tshernova	*
13. *Ecdyonurus baekdu* Bae	***
14. *Heptagenia kihada* Matsumura	*
15. *Heptagenia kyotoensis* Gose	*
Family Isonychiidae	
16. *Isonychia japonica* (Ulmer)	*
17. *Isonychia ussurica* Bajkova	*
Family Metretopodidae	
18. *Metretopus borealis* Eaton	**
Family Polymitarcyidae	
19. *Ephoron shigae* (Takahashi)	**
Family Potamanthidae	
20. *Potamanthus yooni* Bae and McCafferty	*
21. *Rhoenanthus coreanus* (Yoon and Bae)	*

Taxa	Grade
Order Odonata	
Family Coenagrionoidae	
22. *Mortonagrion selenion* (Ris)	***
23. *Ceriagrion melanurum* Selys	*
24. *Nehalenia speiciosa* (Charpentier)	**
25. *Enallagma cyathigerum* (Charpentier)	**
Family Lestidae	
26. *Lestes sponsa* (Hansemann)	*
27. *Lestes japonicus* Selys	*
28. *Indolestes gracilis pregrinus* (Ris)	*
Family Calopterygidae	
29. *Mnais strigsata* Selys	**
Family Gomphidae	
30. *Gomphidia confluens* Selys	*
Family Aeshnidae	
31. *Gynacantha japonica* Bartenef	*
32. *Boyeria maclachlani* Selys	**
33. *Aeschnophlebia anisoptera* Selys	**
34. *Anax parthenope julius* Brauer	*
35. *Aeshna crenata* Hagen	*
36. *Aeshna nigroflava* Martin	*
37. *Aeshna coerulea* (Strön)	*
38. *Aeshna juncea* (Linnaeus)	*
Family Cordulegastridae	
39. *Anotogaster sieboldii* Selys	*
Family Corduliidae	
40. *Cordulia aenea amurensis* Selys	*
41. *Somatochlora arctica* (Zatt)	*
42. *Somatochlora graeseri* Selys	*
43. *Somatochlora alpestris* (Selys)	*
44. *Macromia manchuria* Asahina	*
Family Libellulidae	
45. *Nannophya pygmaea* Rambur	***
46. *Tramea virginia* (Rambur)	**
47. *Crocothemis servilia* (Drury)	**
48. *Lyriothemis pachygastra* (Selys)	*
49. *Libellula angelina* Selys	*
50. *Libellula quadrimaculata* Linnaeus	*
51. *Sympetrum danae* Sulzer	*
52. *Sympetrum pedemontanum pedemontanum* (Allioni)	*
53. *Pseudothemis zonata* (Burmeister)	*
54. *Rhyothemis fulignosa* Selys	**
55. *Deielia phaon* (Selys)	*
Order Plecoptera	
Family Scopuridae	
56. *Scopura laminata* Uchida	***
Family Nemouridae Newman	
57. *Nemoura jezoensis* (Okamoto)	*

Taxa	Grade
58. *Amphinemura verrucosa* Zwick	*
Family Capniidae Klapalek	
59. *Eucapnopsis stigmatica* Okamoto	*
60. *Paracapnia recta* Zhiltzova	*
Family Leuctridae Klapalek	
61. *Leuctra fusca* (Linnaeus)	*
62. *Paraleuctra cercia* Okamoto	*
63. *Rhopalopsole mahunkai* Zwick	*
Family Peltoperlidae Claassen	
64. *Yoraperla han* Stark and Nelson	**
65. *Yoraperla uchidai* Stark and Nelson	**
Family Pteronarcyidae Smith	
66. *Pteronarcys macra* Ra, Baik, and Cho	**
Family Perlodidae Klapalek	
67. *Perlodes stigmata* Ra, Kim, Kang, and Ham	*
68. *Isoperla flavescens* Zhiltzova and Potikha	*
Family Perlidae Latreille	
69. *Oyamia nigribasis* Banks	*
70. *Paragnetina flavotincta* (McLachlan)	*
71. *Paragnetina tinctipennis* (McLachlan)	*
Family Chloroperlidae Okamoto	
72. *Alloperla joosti* Zwick	*
73. *Alloperla rostellata* (Klapalek)	*
Order Hemiptera	
Family Corixidae	
74. *Hesperocorixa kolthoffi* (Lundbald)	*
75. *Sigara* (*Tropocorixa*) *nigroventralis* (Matsumura)	*
76. *Cymatia apparens* (Distant)	*
77. *Micronecta* (*Micronecta*) *guttata* Matsumura	*
Family Notonectidae	
78. *Notonecta* (*Notonecta*) *amplifica* Kiritshenko	*
Family Pleidae	
79. *Plea* (*Paraplea*) *japonica* (Horváth)	**
Family Naucoridae	
80. *Ilyocoris exclamationis* (Scott)	**
Family Aphelocheiridae	
81. *Aphelocheirus nawae* Nawa	*
Family Belostomatidae	
82. *Lethocerus deyrollei* (Vuillefroy)	***
Family Ochteridae	
83. *Ochterus marginatus* Latreille	*
Family Hydrometridae	
84. *Hydrometra okinawana* Drake	*
Family Mebridae	
85. *Hebrus nipponicus* Horvath	*
Family Gerridae	
86. *Aquaris elongatus* (Uhler)	*
87. *Rhyacobates esaki* Miyamoto and Lee	*

Taxa	Grade
88. *Asclepios shiranui coreanus* Esaki	*
Family Saldidae	
89. *Chiloxanthus pilosus pilosus* (Fallén)	*
Order Megaloptera	
Family Sialidae	
90. *Sialis* KUa	**
Order Coleoptera	
Family Dytiscidae	
91. *Cybister* (*Cybister*) *japonicus* Sharp	**
Family Gryinidae	
92. *Gyrinus* (*Gyrinus*) *japonicus francki* Ochs	*
Family Hydrophilidae	
93. *Hydrophilus accuminatus* Motschulsky	**
Family Lampyridae	
94. *Hotaria papariensis* (Doi)	***
95. *Luciola lateralis* Motschulsky	***
96. *Lychnuris rufa* (Oliver)	***
Order Hymenoptera	
Family Agriotypidae	
97. *Agriotypus gracilis* Waterston	**
Order Diptera	
Family Blepharoceridae	
98. *Philorus* KUa	*
99. *Bibiocephala* KUa	*
Order Trichoptera	
Family Stenopsychidae	
100. *Stenopsyche griseipennis* McLachlan	**
101. *Stenopsyche bergeri* Martynov	**
Family Philopotamidae	
102. *Wormaldia* KUa	*
Family Rhyacophilidae	
103. *Rhyacophila retracta* Martynov	*
Family Phryganeidae	
104. *Agrypnia pagetana* Curtis	**
Family Brachycentridae	
105. *Micrasema* KUa	*
Family Limnephilidae	
106. *Hydatophylax nigrovittatus* McLachlan	*
Family Lepidostomatidae	
107. *Molanna moesta* Banks	*
Family Helicopsychidae	
108. *Helicopsyche yamadai* Iwata	***
Family Leptoceridae	
109. *Ceraclea* KUa	*

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