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Temporal Changes of Community Structure of Benthic Macroinvertebrates in the North Branch of Han River System, Korea

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Abstracts - The ephemeropterans such as *Epeorus pellucidus, Uracanthella rufa* and *Drunella aculea* were dominated in station 1. It was generally showed the stable aquatic communities with low dominance index values throughout the year in station 2. The first dominant species in station 3 were all mayflies with the average DI value of 0.38. The first dominant species of *Uracanthella rufa* known as relatively tolerant species in station 4. A crustacean species *Gammarus* spp. have frequently occurred as the 1st or 2nd dominant species in station 5. *Limnodrilus socialis*, and *Chironomus* spp. were dominated in stations 6 and 7. Station 1, 2 and 3 were classified as oligosaprobic status according to their average diversity index values ranging from 3.46 to 3.52. Station 7 showed α-mesosaprobic water condition with the overall average diversity value of 1.26. In general, the equitability and species richness values in the same sampling areas had close relations with their diversity values. The dendrogram drawn by dissimilarity values among 7 sampling sites indicates that the macrobenthic communities were divided into 3 groups: stations 1, 2, 3 and 4; stations 6 and 7; and station 5 alone. [Macroinvertebrates, North branch of Han River system, Water quality].

INTRODUCTION

Macroinvertebrates (mostly arthropods) are the important component of the aquatic ecosystem and have long been used to evaluate the water quality of streams (Rosenberg & Resh 1993). Although Soh *et al.* (1979) investigated the protozoans in Han River to determine the biological indicators in polluted water, macroinvertebrates are probably best suited among members of the aquatic ecosystem, because they are numerous in almost every stream, are readily collected, are not very mobile and generally have life cycles of a year or more. Moreover, macroinvertebrates including the aquatic insects are generally reduced or eliminated from the ecosystem during pollutional stresses and do not reappear until the aquatic ecosystem *per se* returns normally.

Hynes (1960) and Cairns & Dickson (1973) are among the significant historical publications on the subject. A few studies on water quality and biological fauna have been carried out in Korea, mainly in the Han River system (Yoon 1978; Kim *et al.* 1980; Yoon & Byun 1981; Yoon *et al.* 1986; Ra & Cho 1986; Yoon *et al.* 1987; Chung *et al.* 1992; Bae *et al.* 1993).

The objective of this study was to assess temporal changes of dominant, species diversity, equitability and species richness index values in benthic communities of the Han River system.

SITES STUDIES

The northern branch of Han River is 317.5 km in length, and has five man-made reservoirs; namely Hwachon, Chunchon, Soyang, Euiam and Chongpyong dams. Our sampling sites were located on three tributaries of the north branch.

The Sagimak-Chon (Chon means stream) (station 1) was regarded as the cleanest tributary, while Masok-Chon (stations, 5, 6 and 7) was selected as a severely stressed stream. The Chochong-Chon (stations 2, 3 and 4) has been assessed as moderately polluted stream (Environmental Office/ROK 1991, Fig. 1). Therefore, stations 1, 3 and 7 (sequentially from least to worst polluted) were mainly compared in this study. The sampling stations in all tributaries were similar in regard to size, substrate and currents.

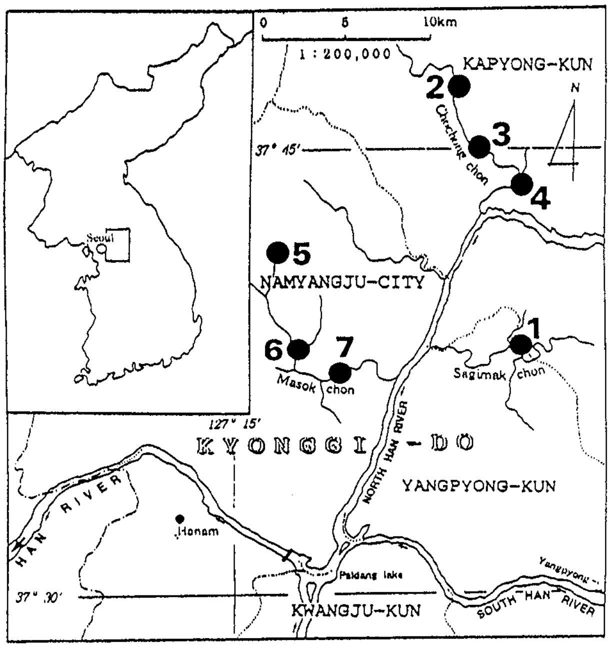

Fig. 1. A map of showing the sampling stations of the benthic macroinvertebrates at the tributaries of the north branch of Han River system, Korea.

MATERIALS AND METHODS

1. Sample collection and identification

Macroinvertebrates were collected qualitatively or quantitatively by means of a Surber sampler from the 7 sampling stations of the north branch of the Han River system during January -December 1993.

All the organisms picked from the debris were identified using the taxonomic references (Hilsenhoff 1975; Cummins 1978; Pennak 1978; Wiggins 1978; Merrit & Cummins 1984; Kawai 1985; Yoon 1988, 1995; Kwon 1990; Yoon & Kim 1992; Lee 1992). Oligochaete worms (Oligochaeta), midge larvae (Diptera: Chironomidae) and scuds (Amphi-poda) were subsampled during the identification process as described elsewhere (Simpson 1980). For all other groups every organism was identified individually.

2. The parameters used in data interpretation

Dominance index values (DI) were calculated from McNaughton's formula (1967). Species diversity values were calculated from the modified Shannon-Weaver's formula (Wilhm 1972). Indices were calculated for all samples for each station. The surveyed areas were divided by the following saprobic system according to species diversity index (H′) values (Staub *et al.* 1970; Yoon *et al.* 1984). Equitability (E) is a measure of evenness of the distribution of individuals among the component species (Pielou 1977). Species richness (RI) in each station was calculated by the Margalef's index (1958). Similarity coefficients were calculated in the procedures described by Burlington (1962). Dissimilarities (1-similarity) between possible pairings of the sampling stations were calculated in this study, and the cluster analysis for establishing the dendrogram was done by the SAS package computer program.

RESULTS

1. Macroinvertebrates collected from the north branch of the Han River

The benthic macroinvertebrates in total surveyed areas were composed of 150 species, 110 genera, 63 families, 15 orders, 6 classes in 4 phyla (Table 1), and a total of 17,825 organisms were collected in seven stations and identified during the course of this study (Table 2). Most of the macroinvertebrates collected were aquatic insects composed of 134 species, 95 genera, 50 families in 8 orders. Among them, ephemeropteran taxa showed the most abundant number of species with 40 species in 10 families. The rests of taxa were as follows in decreasing order of species number: Trichoptera with 27 species in 10 families, Diptera with 25 species in 11 families, Coleoptera with 12 species in 4 families, Ple-

Table 1. Number of taxa collected from each station of the north branch of Han River system during one-year survey period (1993)

Stream	St. No.	Phylum	Class	Order	Family	Genus	Species
Sagimak-Chon	1	3	5	13	41	75	107
	Total	3	5	13	41	75	107
Chochong-Chon	2	4	5	11	35	56	83
	3	4	4	10	41	66	94
	4	4	5	11	30	48	67
	Total	4	5	11	48	82	107
Masok-Chon	5	3	4	10	26	34	44
	6	4	6	10	17	20	25
	7	4	6	12	21	26	31
	Total	4	6	13	34	49	64
Total		4	6	15	63	110	150

Table 2. Numbers of species and individuals collected in each station during one-year survey period (1993)

Month		Station No.							Total (Ind. No.)
		1	2	3	4	5	6	7	
Jan.	Sp. No.	7	–	24	–	–	–	2	
	Ind. No.	17	–	308	–	–	–	39	364
Feb.	Sp. No.	10	21	24	4	–	–	4	
	Ind. No.	34	317	457	5	–	–	690	1,503
Mar.	Sp. No.	25	20	29	19	15	6	9	
	Ind. No.	161	259	758	554	243	220	47	2,242
Apr.	Sp. No.	16	19	30	22	13	5	3	
	Ind. No.	68	150	717	338	60	68	471	1,872
May	Sp. No.	15	16	20	6	15	8	5	
	Ind. No.	42	115	143	70	88	172	184	814
Jun.	Sp. No.	33	23	17	21	14	11	7	
	Ind. No.	106	216	111	372	131	60	1,273	2,269
Jul.	Sp. No.	6	12	9	13	8	5	3	
	Ind. No.	7	20	21	32	79	22	43	224
Aug.	Sp. No.	15	17	10	14	14	13	5	
	Ind. No.	37	102	44	30	125	48	1,062	1,448
Sep.	Sp. No.	14	16	18	14	16	13	9	
	Ind. No.	23	56	128	39	122	38	212	618
Oct.	Sp. No.	22	16	18	14	12	7	9	
	Ind. No.	61	86	169	71	128	44	53	612
Nov.	Sp. No.	25	21	26	26	12	3	11	
	Ind. No.	202	134	1,191	1,417	317	53	70	3,384
Dec.	Sp. No.	33	24	25	24	10	3	77	
	Ind. No.	540	270	939	396	58	102	170	2,475
Total (Ind. No.)		1,834	1,725	6,008	3,324	1,351	827	5,730	17,825

Remarks : Sp. No. = Number of species collected
Ind. No. = Number of individual collected

coptera with 10 species in 4 families and Odonata with 10 species in 3 families. Excluding the aquatic insects, the following benthic macroinvertebrates were collected; crustaceans (4 species in 3 families), oligochaetes and hirudineans (5 species in 3 families), gastropods (6 species in 5 families), and only one species of platyhelminthes, a planaria *Phagocata kawakatsui* (data not shown in Tables).

2. Dominant species and dominance index values (DI)

The monthly dominant species and dominance index values (DI) in the sampling stations are listed and calculated in Table 3.

The first dominant species in station 1 were mainly the ephemeropterans (mayflies), though the second dominant species were extremely variable. During the spring season (March, April and May), a mayfly *Epeorus pellucidus* and a fly *Chironomus* sp. 1 were dominant species with the average DI value of 0.33. During the summer season (June, July and August), three taxa, *Epeorus pellucidus, Serratella uracanthella* and *Semisulcospira gottschei*, were predominant with the DI value of 0.46 which is a slightly higher number compared to other values. It is considered that the gastropods, like *Semisulcospira gottschei*, largely coincide with a July algal bloom on the substrates caused by organic influx from the upper stream. During the fall season (September, October and November), typical stream dwellers, *Drunella aculea*, and *Semisulcospira gottschei*, were predominant with a relatively low DI value of 0.26. During the winter season (December, January and February), three taxa, *Drunella aculea, Cheumatopsyche brevilineata* and *Antocha* spp., mainly occurred in this station with the average DI value of 0.28 (Table 3). Noticeably, a dipteran species, *Antocha* sp., occurred in January as the first dominant species of station 1. However, taxonomical, ecological and life cycle studies on genus *Antocha* have not been carried out so far in Korea.

The first dominant species in station 2 were *Epeorus pellucidus, Protohermis grandis* and *Cheumatopsyche brevilineata*, and the second dominant species were mainly the ephemeropterans (mayflies) and trichopterans (caddisflies) with the average DI value of 0.37. This station showed, in general, the similar biological features as station 1. During the spring season, only one taxon, *Epeorus pellucidus*, was recorded as the first dominant species with the average DI value of 0.44. During the summer season, the first dominant species were variable according to the months, which indicates serious competition amongst species. Especially, a pollution-tolerant fly species, *Chironomus* spp. occurred in this station in July as the first dominant species caused, presumably, by organic influx from the upper stream in July, similar to station 1. During the fall season, a megalopteran species, *Protohermis grandis* and *Epeorus pellucidus* were the first dominant species with the average DI value of 0.34. It might be elucidated that the habitats of station 2 had returned back to favorable conditions for the carnivore, *Protohermis grandis* to survive during the fall season. At that time, the station was composed of diverse benthic communities with the low DI values. In the winter season, the taxa *Cheumatopsyche brevilineata* and *Ecdyonurus* spp. contributed as the first and second dominant species, respectively, with the average DI value of 0.38. Station 2 generally showed the most stable aquatic communities amongst the stations surveyed, with the stable low DI values throughout the year.

The first dominant species in station 3 were all the mayflies with the average DI value of 0.38, although the caddisflies were included in the second dominant species. The DI value during the summer season was a little higher (0.44) than those during the other seasons (less than 0.38). The dominant species during the summer season were all the mayflies; but, different species occurred according to the months. In contrast, the first and second dominant species during the winter season *Serratella uracanrhella* and *Cheumatopsyche brevilineata*, respectively, remained throughout the season.

The first dominant species in station 4 were *Serratella rufa* known as relatively tolerant species among mayfly larvae with an average DI value of 0.55. During the summer season, the first dominant species were mainly *Limnodrilus socialis* regarded as a pollution-tolerant species.

Station 5 is a small and cold stream located upstream of the other stations surveyed in this study. In our experience, many small streams typically have lower diversity than larger streams in similar habitats and with similar substrates. Therefore, only qualitative collections of the benthos were done in this station. Throughout all seasons, a crustacean species, *Gammarus* spp., frequently occurred as the first or second dominant species in this station. It is also noteworthy that the population of *Simulium* flies were dominantly increased in March.

Station 6 is although located in the upper part of the stream, is downstream of small streams flowing from Chonmasan Valley which is one of the public resorts in the Seoul area. During the spring season, *Limnodrilus socialis* and *Chironomus* sp. 1 known as the pollution-tolerant spec-

Table 3. Dominant species and indices (DI) in the stations of Han river system during one-year survey period (1993)

Station	Month	1st dominant species	2nd dominant species	DI
	Jan.	*Antocha* sp.	*Epeorus pellucidus*	0.25
	Feb.	*Cincticostella tshernovae*	*Chironomus* sp.1	1 0.56
	Mar.	*Chironomus* sp. 1	*Epeorus pellucidus*	0.40
	Apr.	*Epeorus pellucidus*	*Uracanthella rufa*	0.34
	May	*Epeorus pellucidus*	*Chironomus* sp.1	1 0.26
	Jun.	*Epeorus pellucidus*	*Choroterpes altioculus*	0.19
1	Jul.	*Semisulcospira gottschei*	*Epeorus pellucidus*	0.43
	Aug.	*Epeorus pellucidus*	*Uracanthella rufa*	0.76
	Sep.	*Semisulcospira gottschei*	*Uracanthella rufa*	0.26
	Oct.	*Semisulcospira gottschei*	*Drunella aculea*	0.26
	Nov.	*Drunella aculea*	*Cheumatopsyche brevilineata*	0.27
	Dec.	*Cheumatopsyche brevilineata*	*Drunella aculea*	0.31
	Feb.	*Cheumatopsyche brevilineata*	*Ecdyonurus levis*	0.45
	Mar.	*Epeorus pellucidus*	*Antocha* sp.	0.50
	Apr.	*Epeorus pellucidus*	*Cheumatopsyche brevilineata*	0.41
	May	*Epeorus pellucidus*	*Cheumatopsyche brevilineata*	0.41
	Jun.	*Uracanthella rufa*	*Limnodrilus socialis*	0.42
2	Jul.	*Chironomus* sp. 1	*Uracanthella rufa*	0.30
	Aug.	*Epeorus pellucidus*	*Rhyacophila shikotsuensis*	0.26
	Sep.	*Epeorus pellucidus*	*Protohermis grandis*	0.38
	Oct.	*Protohermis grandis*	*Epeorus pellucidus*	0.30
	Nov.	*Protohermis grandis*	*Hydropsyche* KUe	0.34
	Dec.	*Cheumatopsyche brevilineata*	*Ecdyonurus joernensis*	0.30
	Jan.	*Uracanthella rufa*	*Cheumaropsyche brevilineata*	0.30
	Feb.	*Uracanthella rufa*	*Epeorus pellucidus*	0.44
	Mar.	*Hydropsyche* KUa	*Cheumaropsyche brevilineata*	0.32
	Apr.	*Uracanthella rufa*	*Epeorus pellucidus*	0.42
	May	*Epeorus pellucidus*	*Uracanthella rufa*	0.28
	Jun.	*Rhoenanthus coreanus*	*Epeorus pellucidus*	0.27
3	Jul.	*Alanities muticus*	*Uracanthella rufa*	0.55
	Aug.	*Epeorus pellucidus*	*Uracanthella rufa*	0.49
	Sep.	*Epeorus pellucidus*	*Uracanthella rufa*	0.32
	Oct.	*Cheumatopsyche brevilineata*	*Epeorus pellucidus*	0.35
	Nov.	*Uracanthella rufa*	*Cheumatopsyche brevilineata*	0.43
	Dec	*Uracanthella rufa*	*Cheumatopsyche brevilineata*	0.39
	Feb.	*Protohermis grandis*	*Hydropsyche* KUa	0.60
	Mar.	*Uracanthella rufa*	*Antocha* sp.	0.52
	Apr.	*Uracanthella rufa*	*Antocha* sp.	0.54
	May	*Uracanthella rufa*	*Antocha* sp.	0.88
	Jun.	*Limnodrilus socialis*	*Hydropsyche* KUa	0.62
4	Jul.	*Uracanthella* rufa	*Epeorus pellucidus*	0.47
	Aug.	*Limnodrilus socialis*	*Uracanthella rufa*	0.40
	Sep.	*Uracanthella rufa*	*Cheumato psyche brevilineata*	0.45
	Oct.	*Cheumatopsyche brevilineata*	*Hydropsyche* KUe	0.37
	Nov.	*Uracanthella rufa*	*Baeties fuscatatus*	0.58
	Dec.	*Uracanthella rufa*	*Cheumatopsyche brevilineata*	0.58
	Mar.	*Simulium* sp.	*Cincticostella levanidovae*	–
	Apr.	*Cincticostella*	*levanidovae Gammarus* sp.	–
	May	*Epeorus curvatulus*	*Gammarus* sp.	–
	Jun.	*Simulium* sp.	*Gammarus* sp.	–
	Jul.	*Gammarus* sp.	*Limnodrilus socialis*	–
5	Aug.	*Gammarus* sp.	*Epeorus curvatulus*	–

Table 3. Continued

Station	Month	1st dominant species	2nd dominant species	DI
	Sep.	*Gammarus* sp.	*Bleptus fasciatus*	–
	Oct.	*Gammarus* sp.	*Ephemera strigata*	–
	Nov.	*Gammarus* sp.	*Ephemera strigata*	–
	Dec.	*Heptagenia kihada*	*Gammarus* sp.	–
6	Mar.	*Limnodrilus socialis*	*Chironomus* sp. 1	–
	Apr.	*Limnodrilus socialis*	*Chironomus* sp. 1	–
	May	*Limnodrilus socialis*	*Chironomus* sp. 1	–
	Jun.	*Baeties fuscatatus*	*Limnodrilus socialis*	–
	Jul.	*Baeties fuscatatus*	*Limnodrilus socialis*	–
	Aug.	*Barbronia weberi*	*Limnodrilus socialis*	–
	Sep.	*Erpobdella lineata*	*Chironomus* sp. 1	–
	Oct.	*Chironomus* sp. 1	*Chironomus* sp. 2	–
	Nov.	*Chironomus* sp. 2	*Chironomus* sp. 1	–
	Dec.	*Chironomus* sp. 2	*Chironomus* sp. 1	–
7	Jan.	*Limnodrilus socialis*	*Chironomus* sp. 2	0.91
	Feb.	*Limnodrilus socialis*	*Chironomus* sp. 1	1.00
	Mar.	*Chironomus* sp.1	*Procladius* sp.	0.66
	Apr.	*Limnodrilus socialis*	*Chironomus* sp. 1	0.99
	May	*Limnodrilus socialis*	*Chironomus* sp. 1	0.97
	Jun.	*Limnodrilus socialis*	*Chironomus* sp. 1	0.97
	Jul.	*Baeties fuscatatus*	*Limnodrilus socialis*	0.98
	Aug.	*Baeties fuscatatus*	*Limnodrilus socialis*	0.99
	Sep.	*Chironomus* sp.1	*Cloeon dipterum*	0.82
	Oct.	*Limnodrilus socialis*	*Physa acuta*	0.68
	Nov.	*Hydropsyche* KUb	*Physa acuta*	0.62
	Dec.	*Hydropsyche* KUb	*Hydropsyche* KUe	0.42

ies were collected as the first and second dominant species, respectively. Although *Baetis fuscatatus*, *Limnodrilus socialis* and *Chironomus* spp. were acting as the first and second dominant species during the summer and fall seasons, it is very interesting that the leech predating the oligochaetes, *Erpobdella lineata*, occurred predominantly in September.

Station 7 is located downstream from station 6. The highest average DI value (0.83) of the study was recorded in this station. During the spring season, two taxa, *Limnodrilus socialis* and *Chironomus* sp. 1 were predominant with the DI value of 0.87 as in the station 6. During summer, *Baetis fuscatatus* and *Limnodrilus socialis* acted as the first and second dominant species with the highest DI value of 0.98. As in station 6, *Baetis fuscatatus* also occurred in this station especially during the summer season, which means that these small mayflies have emerged as adults during this season. Especially, *Hydropsyche* spp. and *Physa acuta* occurred during the fall and winter seasons.

In summarizing the above results obtained from species compositions and the DI values in the stations surveyed in this study, station 1, 2 and 3 were similar each other in terms of a clean aquatic ecosystem (DI values ranged from 0.36 to 0.38). In contrast, stations 6 and 7 in Masok-Chon were regarded as the most polluted sites, mainly with oligochaetes and chironomid worms according to season.

3. Species diversity, equitability and species richness values

The monthly values of species diversity in the main sampling stations are shown in Fig. 2. Station 1 showed the annual average diversity value of 3.52, suggesting that this station was classified as oligosaprobic status on the basis of the saprobic classes by species diversity. The diversity values during the most of survey period were at least more than 3.0 in station 1, while the values were less than 3.0 in January (2.49), February (2.69) and July (2.52). Station 3, showing the overall average diversity value of 3.46,

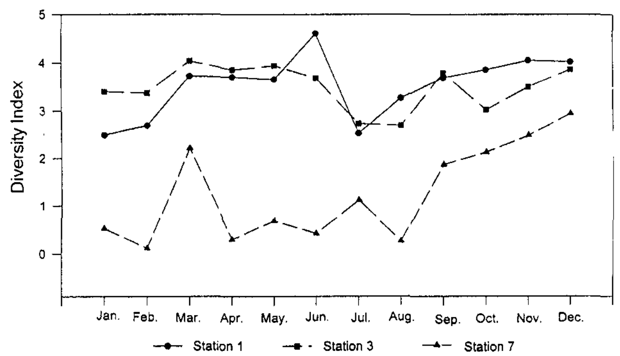

Fig. 2. Species diversity index (H′) values in the main stations of the Han River system during one-year survey period, 1993.

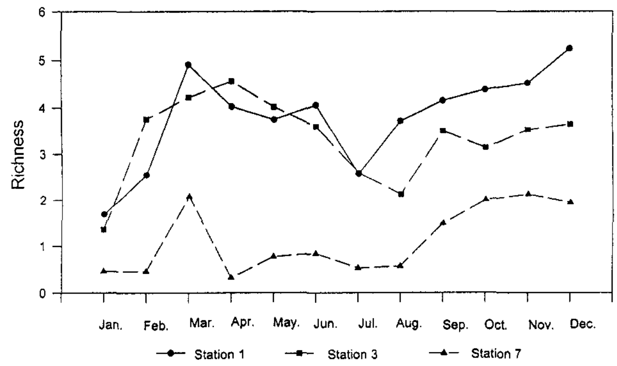

Fig. 4. Species richness index (RI) values in the main of the Han River system during one-year survey period, 1993.

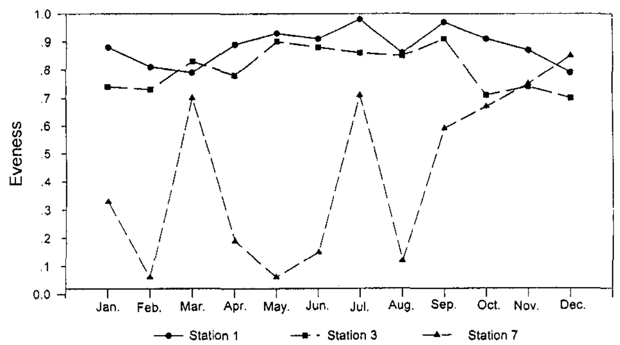

Fig. 3. Equitability (E) values in the main stations of the Han River system during one-year survey period, 1993.

was also classified as oligosaprobic as in station 1. However, the average diversity value during the summer season was less than 3.0 (2.93), regarded as β-mesosaprobic. The monthly diversity values in station 7 ranged from 0.12 to 2.94. This station generally showed α-mesosaprobic water condition with the overall average diversity value of 1.26. However, the season showing the worst water quality in this station was summer with the average diversity value of 0.61, regarded as a polysaprobic condition. Although the highest values were calculated in November (2.48) and December (2.94), the diversity values in the dry season of January and February were 0.53 and 0.12, respectively. Even in April and May, the values were less than 1.00 (0.30 in April, 0.69 in May).

The monthly evenness values of the distribution of taxa at main stations 1, 3 and 7 are shown in Fig. 3. In the case of stable communities with the high diversity index value of 3.4, the equitability values were more than 0.8 in this study. The overall equitability value in station 1 was 0.88, and about 18 species of macrobenthos per sampling unit were counted in this station. The values ranged from 0.79 in October to 0.98 in July. The average equitability value at station 3 was also very high (0.81), and 20 species of macrobenthos per sampling unit were found in this station. The lowest overall equitability value (0.43) and the lowest number of species per sampling unit (5 species) were recorded in station 7. The lowest values were 0.06 in February, May and 0.12 in August. The individual numbers of the tolerant species, *Limnodrilus socialis* and *Baetis fuscatatus*, highly increased in February and August. In summarizing the results obtained in this section, the stations showing high equitability values over 0.80 were stations 1 and 3, while station 7 showed the lowest average value of 0.43. These values in the sampling stations were generally well matched with the monthly trends of species diversity index values at the same stations (Figs. 2, 3).

The monthly values of species richness in the main sampling stations are shown in Fig. 4. The average RI value in station 1 was 3.80, and the highest value (5.24; 33 species and 540 individuals) was recorded in December. The lowest value in this station was 1.69 (7 species and 17 individuals) in January. The RI values during the four seasons were 4.23 during spring, 3.45 during summer, 4.35 during autumn and 3.16 during winter. At station 3, the average RI value was 3.34, and the seasonal values were 4.27 during spring, 2.27 during summer, 3.39 during autumn and 2.92 during winter. The highest RI

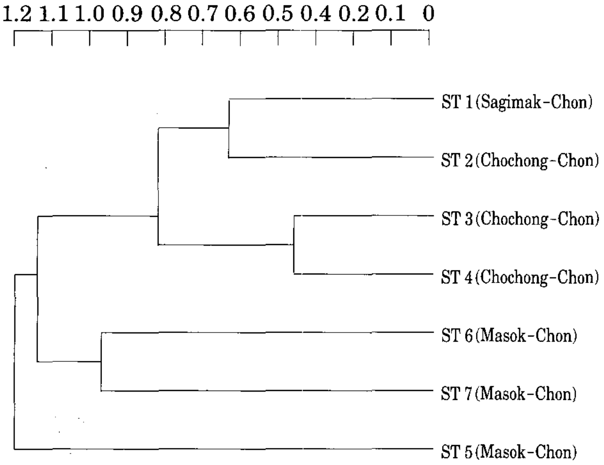

Fig. 5. A dendrogram of dissimilarity values based on the species and individual numbers of all the sampling stations during one-year survey period, 1993.

value (4.27) was recorded during the spring season, while the lowest RI value (2.77) was during the summer season. At station 7, located in one of the most polluted streams in the north branch of the Han River, the lowest average RI value (1.31) was reasonably recorded. Especially, the RI value during the summer season was very low (0.65) at this station. In summarizing the results obtained in this section, the low RI values were usually detected during the summer season, while the relatively high RI values were during the spring season.

4. Similarity coefficients

The dendrogram of the sampling sites (Fig. 5) indicates that the communities (sampling stations) were divided by three groups: 1) stations 1, 2, 3 and 4; 2) stations 6 and 7; and 3) station 5 alone. Species compositions at stations 1 in Sagimak-Chon, and 3 in the upper stream of Chochong-Chon, were similar to each other at the dissimilarity value of 0.53. Stations 3 and 4, which were located in the same stream named Chochong-Chon, were also subdivided at the dissimilarity value of 0.39. Station 7, regarded as the severely polluted tributary, was also reasonably grouped with station 6 at the dissimilarity value of 0.91. Station 6 was located with station 7 in the same stream named Masok-Chon. Station 5 was solely separated differently from the other stations. Station 5 was a small and cold stream located at the most upper part among the stations surveyed in this study. The high contribution of *Gammarus* spp. at station 5 was recorded throughout the seasons.

DISCUSSION

The main stations 1, 3 and 7 showed reasonable diversity values throughout the study as expected. The overall average diversity values of stations 1 and 3 were at least more than 3.0 and classified as oligosaprobic status, while station 7 showed α-mesosaprobic water condition with the overall average diversity value of 1.26 in this study. However, the lowest diversity values were recorded in the dry season of January and February and in the summer season even in stations 1 and 3.

An important drawback of the diversity index is that many small and cold streams have a naturally low diversity regardless of pollution stresses. Small streams typically have lower diversity than larger streams in similar habitats, which may lead to erroneous conclusions about their diversity indices (Hilsenhoff 1977). Therefore, station 5 located at the most upper stream of Masok-Chon, which showed poor species compositions and standing biomasses, was not included in the summary of the diversity values of the sampling stations.

The stations showing high equitability values over 0.8 were stations 1, and 3, suggesting that the benthic communities in these regions were well balanced. Station 7 showed the lowest average value of 0.43. The lowest values were 0.06 in February, May and 0.12 in August. The individual numbers of the tolerant species, *Limnodrilus socialis* and *Baetis fuscatatus*, highly increased in February and August, respectively. These equitability values in the sampling stations were generally well matched with the monthly trends of species diversity values in the same stations.

Although the diversity index also expresses species richness of a community, the richness values in the sampling stations were separately calculated in this study. Station 7 showed the lowest RI values throughout the survey as expected. In all the sampling stations, low RI values were usually detected during the summer season, while the relatively high RI values were during the spring season. These trends are generally well matched with the data of species diversity and equitability in this study.

The dendrogram of 7 sampling sites indicates that the communities were divided into 3 groups: 1) stations 1, 2, 3 and 4; 2) station 6 and 7; and 3) station 5 alone (Fig. 5). These clusterings were reasonably grouped as expected. Station 1 was located at the Sagimak-Chon area, and stations 2, 3 and 4 were located at the Chochong-Chon areas. These two streams were classified together as oligosaprobic conditions by the values of species diversity index, whereas station 7 was classified as α-mesosaprobic. Station 6 was located with station 7 in the same stream named Masok-Chon. Station 5 was a small and cold stream located at the most upper part among the stations surveyed in this study. The high contribution of *Gammarus* spp. throughout the seasons and *Simulium* spp. in March was recorded especially in station 5.

Washington (1984) examined the five similarity indices in aquatic systems. He said that the percentage similarity index (PSC) and Pinkham and Pearson's index (B) appeared to be most favoured for aquatic systems. However, there is a need for further research and field testing of similarity indices for water pollution. It is not clear which of these indices is best to use. The procedures described by Burlington (1962) were employed in this study, and the results obtained were satisfactory.

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북한강 하류 지류에서의 저서 대형무척추동물의 계절적 군집구조

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적 요 - 본 연구는 북한강 수계에 연계되어 있는 사기막천(비오염 지점), 조종천(중등도오염 지점), 마석천(오염 지점)을 대상으로(7개 지점) 저서 대형무척추동물을 1993년 1년간 채집, 분류하고, 우점 지수, 종다양성 지수, 유사도 지수 및 풍부도 지수치를 월별로 비교하여 각 지점에서의 수질을 생물학적 또는 생태학적 기준에 따라 평가하고자 하였다. 사기막천의 1지점에서는 *Epeorus pellucidus, Uracanthella rufa* 및 *Drunella aculea*와 같은 하루살이류가 우점하였고, 조종천의 경우, 상류인 2지점에서는 특별한 우점종없이 다양한 종들이 출현하였으며, 중류인 3지점에서는 하루살이류만이, 하류인 4지점에서는 *Uracanthella rufa*가 우점하였다. 마석천 상류인 5지점에서는 갑각류인 *Gammarus* spp.가, 중, 하류인 6, 7지점에서는 실지렁이류인 *Limnodrilus socialis* 및 *Chironomus* spp.가 절대 우점하였다. 사기막천의 1지점과 조종천의 3지점에서는 종다양성 지수가 3.11-3.93의 범위를 보여 oligosaprobic 오염등급에 속하였다. 마석천의 7지점에서는 평균 종다양성 지수가 1.23으로 α-mesosaprobic 오염등급에 속하였다. 유사도 지수 및 풍부도 지수는 각 조사지점에서 종다양성지수와 같은 유형으로 나타났다. 비유사도 지수치를 상호 비교하여 그린 dendrogram의 유형을 보면, 7개 조사지점에서 1, 2, 3, 4지점, 6, 7지점 및 5지점의 3 group으로 구분할 수 있었다.