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Substrate Composition and Benthic Macroinvertebrate Community in the Streams of the North Branch of Han River

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Abstract - Habitat preferences of benthic macroinvertebrates were studied according to the different substrate composition. Although it was hard to determine the common dwellers in the habitats with cobbles and pebbles, some taxa such as *Ephemera orientalis, Davidius lunatus, Tipula* KUb, *Isonychica japonica* and *Tabanus amaenus* etc. occurred preferably in the habitats with gravel/sand. In all the sampling stations, the numbers of species collected in the habitats with gravel/sand were always remarkably smaller as compared with the habitats with cobbles and pebbles. [Macroinvertebrates, North branch of Han River, Habitat preference].

INTRODUCTION

Macroinvertebrates are the important component in the aquatic ecosystem and have long been used to evaluate the water quality of streams (Hilsenhoff 1977). 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 eliminated from the ecosystem during pollution stresses and do not reappear until the aquatic ecosystem *per se* returns normally.

Many limnological studies on water quality and biological fauna have been done mainly in the Han River system in Korea (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.* 1995). Also, few studies on the microhabitats of macroinvetebrates have been done by Yoon *et al.* (1989) and Kim *et al.* (1998).

However, the analytical studies on the habitat preference of macroinvertebrates occurring in the north branch of Han River have not been listed in any publication. Knowing the habitat information of macroinvetebrates can be helped not only to obtain the accurate collecting data, but also to indicate their ecological conditions for evaluating the water quality in the sampling sites.

Therefore, the objective of this study was to assess spacial preference of benthic communities according to the substrate composition of the sampling stations.

MATERIALS AND METHODS

The Han River system originates from the mountainous areas of Kangwon province, drains mid west area of the peninsula. It drains an area of about 26,018 km^2 and 481.7 km long (Environmental Office/ROK 1986). The northern branch of Han River is 317.5 km in length, and has five man-made reservoirs; namely Hwachon, Chunchon, Soyang, Eiam and Chongpyong dams. Our sampling sites were located on two tributaries of the north branch.

The macrobenthos were collected from two ordinary streams of the north branch of the Han

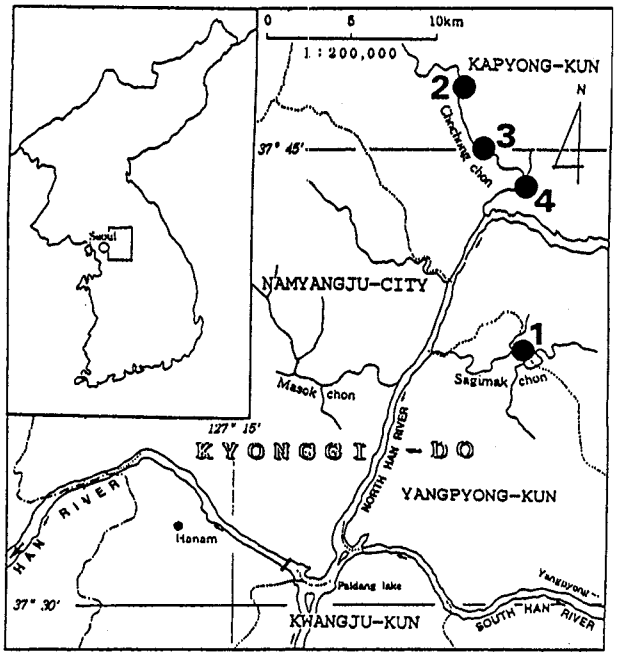

Fig. 1. A map showing the sampling sites of the benthic macroinvertebrates in the streams of the branch of the Han River, Korea

River system. Station 1 is located at Sagimak-Chon, and stations 2, 3, 4 are located at upper- through down-stream of Chochong-Chon (Fig. 1).

The qualitative collections of macroinvertebrates by means of a hand net (90 × 60 cm) were monthly carried out during January through December 1993.

These collections were done according to the substrate conditions at each sampling station. Classification of the substrate compositions was modified by the methods of previous investigators (Wentworth 1922; Minshall 1984; Oh & Chon 1991). Cobble (over 10 cm), pebble (3 ~ 10 cm) and gravel/sand (less than 3 cm) were divided by the diameter of bottom sediments.

All the organisms picked from the debris were identified using the taxonomic references (Tsuda 1962; Kawata 1962; Hilsenhoff 1975; Cummins 1978; Pennak 1978; Wiggins 1978; Kawai 1985; Yoon 1988; Kwon 1990; Yoon & Kim 1992; Lee 1992). Oligochaete worms (Oligochaeta), midge larvae (Diptera: Chironomidae) and scuds (Amphipoda) were subsampled during the identification process as described elsewhere (Simpson 1982). For all other groups every organism was identified individually.

The relative occurring frequencies (%) of taxa collected from 144 sampling units according to three different substrate compositions of four stations (4 stations × 3 different substrates × 12 months) were calculated, and relative frequencies (%) shown in this study were calculated simply by the percentage of occurrence of the taxa (species) in the sampling units (48 units in each substrate condition).

The preference index (PI) of each species for the substrate was calculated by a formula as follows;

$$PI = INT\left(\frac{Sp_i\ Su_k}{\Sigma Sp_i} \times \frac{Sp_i\ Su_k}{\overline{Su_k}} \times 10 + 0.5\right)$$

where,

$Sp_i\ Su_k$ = occurrence No. of species i in substrate k

ΣSp_i = total occurrence No. of Sp_i in three types of substrate

$\overline{Su_k}$ = total occurrence No. in substrate k divided by total No. of species occurred in substrate k

The preference index of a species reflects relative occurring frequency of the species collected from 144 sampling units according to three different substrate compositions of four stations (4 stations × 3 different substrates × 12 months), and modified by a weight value which is calculated by occurrence number of a species divided by average occurrence number of total species collected in a substrate texture. The preference index values were plotted as "+" symbol in Table 2. The symbol "+" was given as an index value of "1".

RESULTS

Relative occurring frequencies (%) and relative frequencies (%) of the taxa occurred in the different substrate conditions are listed in Table 1.

A total of 96 taxa were collected from 48 sampling units with cobbles. Among 96 taxa, the mayflies were composed of 37 species, and *Uracanthella rufa* (85%), *Epeorus pellucidus* (75%) and *Rhoenanthus coreanus* (46%) showed their high relative frequencies. Among 15 species of caddisflies found in the sampling units, *Cheumatopsyche brevilineata* (75%), *Hydropsyche* spp. (46 ~ 52%) and *Glossosoma* KUa (44%) showed the high relative frequencies in this substrate. *Davidius lunatus* (13%) showed the highest relative frequency among 4 species of odonates. *Per-*

Table 1. Relative occurring frequencies (%) and relative frequencies (%) of the species occurred according to the substrate condition

Family	Species	Relative occurring frequencies (%)			Relative frequencies (%)		
		CO	PE	GS	CO	PE	GS
Ephemeroptera							
Siphlonuridae	*Siphlonurus chanke*	2	–	2	50	–	50
	Ameletus montanus	4	–	4	50	–	50
Baetidae	*Baetis thermicus*	6	13	6	25	50	25
	Baetis fuscatus	27	21	10	46	35	18
	Alanites muticus	23	23	8	42	42	15
	Cloeon dipterum	4	4	–	50	50	–
	Pseudocloeon japonica	4	–	–	100	–	–
	Pseudocloeon japonica na	15	6	2	63	27	9
Oligoneuridae	*Isonychica japonica*	2	–	13	25	–	75
Heptageniidae	*Bleptus fasciatus*	13	2	–	75	25	–
	Epeorus pellucidus	75	65	21	46	40	13
	Epeorus curvatulus	4	–	–	100	–	–
	Iron aesculus	6	2	–	60	40	–
	Cinygmula grandifolia	2	–	–	100	–	–
	Cinygmula KUa	8	6	–	57	43	–
	Ecdyonurus levis	40	46	17	39	45	16
	Ecdyonurus kibunensis	21	29	13	33	47	20
	Ecdyonurus dracon	6	6	–	50	50	–
	Ecdyonurus bajkova	25	33	13	35	47	18
	Ecdyonurus joernensis	10	19	6	29	53	18
	Heptagenia kyotoensis	4	2	2	50	25	25
Leptophlebiidae	*Paraleptophlebia chocorata*	2	6	–	25	75	–
	Choroterpes (E.) altioculus	17	17	4	44	44	11
Potamanthidae	*Potamanthus (P.) yooni*	2	8	2	16	67	16
	Potamanthus (P.) formosus	46	60	40	31	41	27
Ephemeridae	*Ephemera strigata*	6	13	10	21	43	36
	Ephemera orientalis	23	27	35	27	32	41
	Ephoron shigae	–	–	2	–	–	100
	Drunella aculea	35	35	8	45	45	10
	Drunella triacantha	2	8	2	16	67	16
	Drunella cryptomeria	4	6	–	40	60	–
	Cincticostella levanidovae	10	10	4	42	42	16
	Cincticostella tshernovae	10	4	6	50	20	30
	Ephacerella longicaudata	15	6	2	63	27	10
	Serratella setigera	19	19	2	47	47	5
	Uracanthella rufa	85	81	40	41	39	19
	Ephemerella dentata	17	21	8	36	45	18
Neoephemeridae	*Neoephemera* KUa	–	10	8	–	56	44
Caenidae	*Caenies* KUa	–	–	2	–	–	100
Odonata							
Calopterygidae	*Calopteryx atrata*	–	–	2	–	–	100
Gomphidae	*Gomphus postacularis*	–	4	–	–	100	–
	Davidius lunatus	13	10	31	23	19	58

Table 1. Contunued

Family	Species	Relative occurring frequencies (%)			Relative frequencies (%)		
		CO	PE	GS	CO	PE	GS
	Onychogomphus ringens	6	10	–	37	63	–
	Nihonogomphus KUa	4	6	8	22	33	44
	Sieboldius albardae	4	2	4	40	20	40
Corduliidae	*Macromia manchuria*	–	–	2	–	–	100
	Macromia amphigena fraenata	–	–	2	–	–	100
Plecoptera							
Nemouridae	*Nemoura tau*	2	–	–	100	–	–
	Amphinemura KUa	2	–	–	100	–	–
Capniidae	*Capnia japonica*	4	–	–	50	25	25
	Eucapnopsis stigmatica	–	2	–	–	100	–
Perlodidae	*Perlodes stigmata*	23	27	8	39	46	14
	Archynopteryx KUa	6	13	4	27	55	18
Perlidae	*Paragnetina flavotincta*	6	2	2	60	20	20
	Neoperla coreensis	2	6	–	25	75	–
	Oyamia nigribasis	2	–	–	100	–	–
Hemiptera							
Aphelocheiridae	*Aphelocheirus nawae*	4	4	8	25	25	50
Gerridae	*Gerris(Aguaris) paludum insularis*	–	–	2	–	50	50
	Gerris(Gerris) lacustris latiabdominis	–	–	4	–	–	100
Megaloptera							
Corydalidae	*Protohermis grandis*	52	46	10	48	42	10
	Parachauliodes continentalis	19	27	13	32	46	21
Trichoptera							
Stenopsychidae	*Stenopsyche griseipennis*	–	–	2	–	–	100
Psychomyiidae	*Psychomyia* KUa	23	17	4	52	38	10
Hydropsychidae	*Hydropsyche* KUa	48	31	8	55	36	9
	Hydropsyche KUb	52	44	15	47	40	13
	Hydropsyche KUc	40	27	8	53	36	11
	Hydropsyche KUd	8	8	2	44	44	11
	Hydropsyche KUe	46	38	13	48	39	13
	Cheumatopsyche brevilineata	75	48	21	53	33	14
	Cheumatopsyche KUa	19	15	6	47	37	16
	Macronema radiatum	–	2	–	–	100	–
Rhycophilidae	*Rhyacophila impar*	4	2	–	67	33	–
	Rhyacophila shikotsuensis	27	25	17	39	36	24
	Rhyacophila nigrocephala	19	21	17	33	37	30
	Rhyacophila KUa	6	2	2	60	20	20
Glossosomatidae	*Glossosoma* KUa	44	27	19	49	30	21
Limnephilidae	*Notopsyche* KUa	2	2	2	33	33	33
	Goera japonica	4	–	–	100	–	–
Lepidostomatidae	*Goerodes* KUa	–	–	2	–	–	100

Table 1. Contunued

Family	Species	Relative occurring frequencies (%)			Relative frequencies (%)		
		CO	PE	GS	CO	PE	GS
Tubificidae	*Limnodrilus socialis*	40	38	40	34	32	34
Pharyngobdellida							
Erpobdelliidae	*Barbronia weberi*	4	6	6	25	37	37
	Erpobdella lineata	2	–	6	25	–	75
Mesogastropoda							
Pleuroceridae	*Semisulcospira gottschei*	35	25	44	34	24	42
	Semisulcospira coreana	2	–	–	100	–	–
Lymnaeidae	*Radix auricularia coreana*	13	8	13	38	25	38
Physidae	*Physa acuta*	10	4	10	42	16	42
Planorbidae	*Hippeutis cantori*	–	2	2	–	50	50
Bithyniidae	*Parafossarulus manchouricus*	–	2	2	–	50	50
Tricladida							
Planariidae	*Phagocata kawakatsui*	10	13	6	36	43	21

Remark : CO = cobble (size : > 10 cm)
PE = pebble (size : 3 ~ 10 cm)
GS = gravel/sand (size : 1 ~ 3 cm)

lodes KUa (23%) also showed the highest relative frequency among 8 species of stoneflies occurring in the sampling units. Fourteen (14) species of dipterans occurred in the units, and *Chironomus* sp. 1 (60%) and *Antocha* spp. (48%) showed relatively higher frequencies. Only one hemipteran species, *Aphelocheirus nawae*, was recorded with the relative frequency value of 4%. Out of two megalopteran species, occurring in the substrate with cobbles, *Protohermis grandis* (52%) occurred more frequently than *Parachauliodes continentalis* (19%). Six coleopteran species were detected in these habitats; but, most of them showed relatively low frequencies; less than 2%. The other taxa mainly included *Limnodrilus socialis* (40%) and a gastropod, *Semisulcospira gottschei* (35%).

A total of 99 taxa were collected from 48 sampling units with pebbles. Out of 99 species, a total of 32 species, less than those in the substrate with cobbles, were occurring on the substrate with pebbles. *Uracanthella rufa* (81%), *Epeorus pellucidus* (65%), *Potamanthus* (P.) *formosus* (60 %), and *Ecdyonurus levis* (46%) were the taxa occurring frequently in the substrate with pebbles. However, *Heptagenia kyotoensis* and *Cloeon dipterum*, etc. showed the low relative frequency values ranging from 2% to 4%. *Davidius lunatus* (10%) and *Onychogomphus ringens* (10%) among 5 odonate species occurring in the substrate with pebbles showed relatively higher frequencies. Among the six plecopteran species, *Perlodes stigmata* (27%) and *Archynopteryx* KUa (13%) showed relatively higher frequencies. A hemipteran species, *Aphelocheirus nawae* (4%), and two megalopteran species, *Protohermis grandis* (46%) and *Parachauliodes continentalis* (27%), were also detected in these habitats. A total of 16 trichopteran species were observed in the habitat with pebbles, and *Cheumatopsyche brevilineata* (48%) and *Hydropsyche* KUb (44%) showed relatively high frequencies among each other. Also, *Macronema radiatum*, *Rhyacophila impar*, *Notopsyche* KUa, and *Mystacides* KUa, etc occurred with a low relative frequency value of 2%. *Neonectes natrix* (8%) and *Psephenoides* KUa (6%) among 8 species of aquatic beetles also occurred frequently. Out of 19 dipteran species detected, *Antocha* sp. and *Chironomus* sp. 1 showed a high relative frequency value of 50%, respectively. The other taxa mainly included *Limnodrilus socialis* (38%) and *Semisulcospira gottschei* (25%) with relatively higher frequency values, as shown

Table 2. Habitat preference of the species occurred in the different substrate composition

Species	Substratum		
	Cobble	Pebble	Gravel/Sand
Uracanthella rufa	++++++++++++++++++++++++++++++--	++++++++++++++++++++++++++++	++++++++++-----------
Epeorus pellucidus	++++++++++++++++++++++++++++----	++++++++++++++++++++++++++----	++++----------
Cheumatopsyche brevilineata	++++++++++++++++++++++++++++++	++++++++++++++++----------	++++----------
Hydropsyche KUa	++++++++++++++++++++++----------	+++++++++-----------	+----------
Protohermis grandis	++++++++++++++++++++----------	++++++++++++++++----------	++----------
Hydropsyche KUb	++++++++++++++++++++----------	++++++++++++++++++----------	+++----------
Glossosoma KUa	++++++++++++++++++----------	+++++++----------	++++++----------
Hydropsyche KUe	++++++++++++++++++----------	++++++++++++----------	+++----------
Hydropsyche KUc	++++++++++++++++----------	+++++++++----------	+----------
Antocha sp.	++++++++++++++++----------	++++++++++++++++++-------	+++++----------
Ecdyonurus levis	++++++++----------	++++++++++++++++++++-----	+++++----------
Baetis fuscatus	++++++++++----------	++++++----------	+++----------
Rhyacophila nigrocephala	++++++++++----------	+++++++++----------	+++++++----------
Drunella aculea	++++++++++----------	++++++++++++----------	++----------
Psychomyia KUa	+++++++++----------	+++++----------	+----------
Rhyacophila shikotsuensis	++++++++----------	++++++----------	++++++++----------
Potamanthus (P.) formosus	++++++++++++----------	++++++++++++++++++----------	++++++++++++++++----------
Limnodrilus socialis	+++++++++----------	++++++++++++----------	++++++++++++++++++----------
Chironomus sp. 1	++++++++++++++++++----------	++++++++++++----------	++++++++++++++++++++++----------
Semisulcospira gottschei	+++++++++----------	+++++----------	++++++++++++++++++++++++++
Cheumatopsyche KUa	++++++++----------	+++++----------	+----------
Alanites multicus	++++++++----------	++++++++----------	++----------
Perlodes stigmata	++++++++----------	++++++++++----------	++----------
Serratella setigera	++++++----------	++++++----------	+----------
Choroterpes (E.) altioculus	++++++----------	++++++----------	+----------
Ecdyonurus kibunensis	++++++----------	++++++++++----------	+++----------
Ecdyonurus bajkova	++++++----------	++++++++++++----------	++++----------
Ephemerella dentata	+++++----------	+++++++----------	++----------
Parachauliodes continentalis	+++++----------	++++++++----------	++++++----------
Procladius sp.	+++++----------	++++++++++----------	++++----------
Physa acuta	++++----------	+----------	++++++----------
Radix auricularia coreana	++++----------	++----------	++++++----------
Cincticostella levanidovae	++++----------	++++----------	+----------
Ephacerella longicaudata	++++++----------	+----------	+----------
Dicranota KUa	++++++++----------	++----------	++----------
Cincticostella tshernovae	+++++----------	+----------	+++----------
Pseudocloeon japonica na	++++++++----------	+----------	----------
Pseudocloeon japonica	++++----------	----------	----------
Bleptus fasciatus	++++----------	----------	----------
Nemoura tau	++++----------	----------	----------
Goera japonica	++++----------	----------	----------
Ceratopogonidae sp.	++++----------	----------	----------

Table 1. Contunued

Family	Species	Relative occurring frequencies (%)			Relative frequencies (%)		
		CO	PE	GS	CO	PE	GS
Leptoceridae	*Mystacides* KUa	–	2	–	–	100	–
Coleoptera							
Dytiscidae	*Neonectes natrix*	4	8	15	15	31	54
	Rhantus pulverosus	–	2	2	–	50	50
	Hydaticus grammicus	2	–	–	100	–	–
	Hydaticus sp.	–	1	–	–	100	–
Hydrophilidae	*Helochares striatus*	2	–	2	50	–	50
Elmidae	*Stenelmis vulgaris*	2	2	–	50	50	–
	Zaitzevia nitida	2	2	–	50	50	–
Psephenidae	*Psephenoides* KUa	2	6	2	20	60	20
	Mataeopsephus KUa	–	2	–	–	100	–
	Eubrianax KUa	–	4	–	–	100	–
Diptera							
Tipulidae	*Tipula* KUb	–	6	15	–	30	70
	Tipula KUe	2	–	8	20	–	80
	Tipula KUf	–	2	2	–	50	50
	Tipula KUh	–	2	2	–	50	50
Limnoniidae	*Pedicia* KUa	–	2	–	–	100	–
	Eriocera KUa	–	2	–	–	100	–
	Antocha sp.	48	50	21	40	42	18
	Dicranota KUa	15	6	8	50	21	29
Dixidae	*Dixa* sp.	–	2	2	–	50	50
Simuliidae	*Simulium* sp.	4	2	2	50	25	25
Ceratopogonidae	*Ceratopogonidae* sp.	4	–	–	100	–	–
Chironomidae	*Chironomus* sp. 1	60	50	50	38	31	31
	Chironomus sp. 2	13	23	17	24	44	32
	Chironomus sp. 3	4	2	2	50	25	25
	Chironomus sp. 4	2	2	2	33	33	33
	Procladius sp.	19	23	13	31	48	21
	Pentaneura sp.	2	4	–	33	67	–
Athericidae	*Atherix* KUa	2	2	–	50	50	–
	Suragina KUa	–	2	–	–	100	–
Dolichopodidae	*Dolichopodidae* sp.	4	2	2	50	25	25
Tabaniidae	*Tabanus amaenus*	2	2	8	17	17	66
Decapoda							
Atyidae	*Neocaridina denticulata koreana*	–	–	2	–	–	100
Amphipoda							
Gammaridae	*Gammarus* sp.	4	2	6	33	17	50
Haplotaxida							

Table 2. Continued

Species	Substratum		
	Cobble	Pebble	Gravel/Sand
Dolichopodidae sp.	+++		+
Iron aesculus	+++	+	
Cinygmula KUa	++		
Amphinemura KUa	++		
Oyamia nigribasis	++		
Hydaticus grammicus	++		
Semisulcospira coreana	++		
Epeorus (Epeorus) curvatulus	++		+
Heptagenia kyotoensis	++		+
Capnia japonica	++		+
Simulium sp.	++		+
Chironomus sp. 3	++		+
Ameletus montanus	++		+++
Gerris (A.) paludum insularis		+	+
Rhantus pulverosus		+	+
Dixa sp.		+	+
Hippeutis (S.) cantori		+	+
Parafossarulus manchouricus		+	+
Stenelmis vulgaris	+	+	
Zaitzevia nitida	+	+	
Atherix KUa	+	+	
Paragnetina flavotincta	+	+	+
Chironomus sp. 4	+	+	+
Aphelocheirus nawae	+	+	+++++
Rhyacophila impar	+	++	
Pentaneura sp.	+	++	
Barbronia weberi	+	++	+++
Nihonogomphus KUa	+	++	++++
Neonectes natrix	+	++	++++++++++++
Eucapnopsis stigmatica		++	
Archytopsyche ladogensis		++	
Macronema radiatum		++	
Mystacides KUa		++	
Hydaticus sp.		++	
Mataeopsephus KUa		++	
Tipula KUf		++	
Pedicia KUa		++	
Eriocera KUa		++	
Suragina KUa		++	
Neoperla coreensis		++	+
Notopsyche KUa		++	+
Cloeon dipterum	++	++	

Table 2. Continued

Species	Substratum		
	Cobble	Pebble	Gravel/Sand
Psephenoides KUa	----------	+++----------	+----------
Paraleptophlebia chocorata	----------	++++----------	----------
Gomphus postacularis	----------	++++----------	----------
Eubrianax KUa	----------	++++----------	----------
Potamanthus (P.) yooni	----------	+++++----------	----------
Drunella triacantha	----------	+++++----------	----------
Drunella cryptomeria	+---------	++----------	----------
Ephemera strigata	+---------	++----------	+++++++---------
Cinygmula grandifolia	+---------	++++----------	----------
Baetis thermicus	+---------	+++++----------	++----------
Archynopteryx KUa	+---------	++++++----------	+----------
Ecdyonurus dracon	+++---------	++----------	----------
Hydropsyche KUd	+++---------	++----------	----------
Phagocata kawatsui	+++---------	+++++----------	++----------
Ecdyonurus joernensis	+++---------	+++++++++----------	++----------
Chironomus sp. 2	+++---------	+++++++++----------	+++++++---------
Onychogomphus ringens	++---------	++++++----------	----------
Siphlonurus chanke	+---------	----------	+----------
Helochares striatus	+---------	----------	+----------
Sieboldius albardae	+---------	----------	++----------
Rhyacophila KUa	+---------	----------	++----------
Gammarus sp.	+---------	----------	+++++----------
Erpobdella lineata	+---------	----------	++++++++---------
Ephoron shigae	----------	----------	+++----------
Caenies KUa	----------	----------	+++----------
Calopteryx atrata	----------	----------	+++----------
Macromia amphigena fraenata	----------	----------	+++----------
Stenopsyche griseipennis	----------	----------	+++----------
Goerodes KUa	----------	----------	+++----------
Neocaridina denticulata koreana	----------	----------	+++----------
Macromia manchuria	----------	----------	++++++----------
Gerris(G.) lacustris latiabdominis	----------	----------	++++++----------
Isonychica japonica	----------	----------	+++++++---------
Tabanus amaenus	----------	----------	+++++++---------
Tipula KUe	----------	----------	++++++++---------
Neoephemera KUa	----------	+++++----------	+++++----------
Tipula KUh	----------	+----------	+++----------
Tipula KUb	----------	+----------	++++++++++++++++++---------
Ephemera orientalis	++++---------	++++++++---------	++++++++++++++++++---------
Davidius lunatus	+++---------	++----------	++++++++++++++++++++++----

in the substrate with cobbles.

A total of 89 taxa (species) were collected from 48 sampling units with gravel and sand. Among 29 ephemeropteran species collected, *Potamanthus (P.) formosus* (40%) and *Ephemera orientalis* (35%) occurred preferably in the substrate with gravel and sand, with high relative frequency values; however, the relative frequency values of *Uracanthella rufa* occurring mainly in the habitat with cobbles and pebbles were remarkably decreased in this habitat. *Davidius lunatus* (31 %) and *Nihonogomphus* KUa (8%) among 5 odonate species, *Perlodes stigmata* (9%) among 4 plecopteran species, and *Aphelocheirus nawae* (8%) among hemipteran species occurred, showed relatively higher frequency values in the gravel/sand substrates as compared with those in the habitats with cobbles and pebbles. *Neonectes natrix* (15%) out of 4 coleopteran species, and *Chironomus* sp. 1 (50%) and *Tipula* spp. among 15 dipteran species were also frequently detected in the gravel/sand habitats rather than the other substrates. Two megalopteran species and 15 trichopteran species distributed in this habitat; but, most of their taxa occurred with low frequency values. On the other hand, *Limnodrilus socialis* (40%) and *Semisulcospira gottschei* (44%) were also regarded as common dwellers in the gravel/sand habitats as compared with the other substrates.

Habitat preferences of the taxa occurred according to the different substrate compositions plotted in Table 2.

Many macroinvertebrates distributed commonly with the higher preference index values in the three substrate compositions. However, some certain specific species might have their own substrate preferences. *Uracanthella rufa, Epeorus pellucidus, Cheumatopsyche brevilineata, Hydropsyche* KUa, *Protohermis grandis, Hydropsyche* KUb, *Glossosoma* KUa, *Hydropsyche* KUe, *Hydropsyche* KUc, *Antocha* sp., *Ecdyonurus levis, Baetis fuscatus, Rhyacophila nigrocephala, Drunella aculea* and *Psychomyia* KUa occurred predominantly in the cobble and pebble substrates.

Rhyacophila shikotsuensis, Potamanthus (P.) formosus, Limnodrilus socialis, Chironomus sp.1, *Semisulcospira gottschei* distributed generally in the three different substrates, therefore these species have no remarkable specific substrate preferences.

Pseudocloeon japonica, Bleptus fasciatus, Nemoura KUa, *Goera japonica, Ceratopogonidae* sp., *Cinygmula* KUa, *Amphinemura* KUa, *Oyamia nigribasis, Hydaticus grammicus, Semisulcospira coreana* occurred only in cobble, although the preference index values were lower than the other macrobenthos. Similar patterns were showed in the pebble composition with *Eucapnosis stigmatica, Archytopsyche ladogensis, Macronema radiatum, Mystacides* KUa, *Hydaticus* sp. *Mataeopsephus* KUa, *Tipula* KUf, *Pedicia* KUa, *Eriocera* KUa and *Suragia* KUa, and in the gravel/sand with *Ephoron shigae, Caenies* KUa, *Calopteryx atrata, Macromia amphigena fraenata, Stenopsyche griseipennis, Goerodes* KUa, *Neocaridina denticulata koreana, Macromia manchuria, Gerris (G.) lacustris latiabdominis, Isonychica japonica, Tabanus amaenus*. Especially *Tipula* KUb, *Ephemera orientalis, Davidius lunatus* occurred mainly in the gravel/sand with the high preference index values. We could assumed that these species might have a preference specificity in their substrate compositions.

In summarizing the results obtained in this study, some taxa such as *Ephemera orientalis, Davidius lunatus, Tipula* KUb. *Isonychica japonica* and *Tabanus amaenus* etc. occurred preferably in the habitats with gravel/sand, though most of macrobenthos were inhabiting preferably in the substrates with cobbles and pebbles.

DISCUSSION

Many factors regulate the occurrence and distribution of stream-dwelling invertebrates. The most important factors are current speed, temperature, substratum and dissolved substances. Hynes (1970) stated in his book entitled "The Ecology of Running Waters", that the fauna of clean stony runs is, in general, richer than that of silty reaches and pools both in number of species and in total biomass, and that the type of substratum controls the types of invertebrate which occur there. In general, it can be stated that the larger the stones, and hence the more complex the substrate, the more diverse is the invertebrate fauna. Sand is a relatively poor habitat with few specimens of few species, apart from its microfauna, but silty sand is richer, and muddy substrates may be very rich in biomass although not in variety of species.

The macrobenthos were collected from two ordinary Korean streams, namely Sagimak-Chon and Chochong-Chon, with the various sub-

strate compositions. Habitat preferences of the taxa occurred according to the different substrate conditions in this study. Some taxa such as *Ephemera orientalis*, *Davidius lunatus*, *Tipula* spp., *Isonychica japonica* and *Tabanus amaenus* etc. occurred preferably in the habitats with gravel /sand, though it is hard to determine the common dwellers especially in the habitats with cobbles and pebbles. *Rhyacophila shikotsuensis*, *Potamanthus (P.) formosus*, *Limnodrilus socialis*, *Chironomus* sp. 1, *Semisulcospira gottschei* acted as dominant species in all the different substrates, suggesting that this species also distributed widely without any habitat preference.

In all the sampling stations 1, 2, 3 and 4, the number of species collected in the habitats with gravel/sand were always remarkably smaller as compared with the habitats with cobbles and pebbles. These results obtained in this study are agreed with those reported by Hynes (1970).

Oh & Chon (1991) also reported that abundances of the benthic taxa were primarily determined by water temperature (seasonal), current velocities and substrate textures (particle sizes). They also emphasized that diversity, evenness and dominance indices were positively correlated with the quantity of the middle-sized large pebbles (3~5 cm in diameter) in stream bed. There was no significant difference between cobble and pebble areas in terms of species composition in this study.

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북한강 지류에서의 하상 조성에 따른 저서성 대형무척추동물의 군집 분포

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적 요 - 본 연구는 북한강 수계에 연계되어 있는 사기막천 및 조종천의 4개 지점을 대상으로 저서 대형무척추동물을 1년간(1993) 하상별로 채집, 분류하였으며, 이들 저서 대형무척추동물의 출현빈도율 및 종내의 상대 빈도율에 따른 각 분류군의 하상 선호도를 살펴보고자 하였다. 채집된 대부분의 대형 무척추동물들은 cobble과 pebble 하상 선호성을 보였으며, *Ephemera orientalis, Davidius lunatus, Tipula* KUb, *Isonychica japonica* and *Tabanus amaenus* 등은 gravel/sand 하상 선호성임을 확인할 수 있었다. 일면, 본 연구을 통하여 cobble과 pebble하상에서 채집된 대형 무척추동물군의 종수는 gravel/sand 하상에서 채집된 종 수에 비해 현저히 많음을 알 수 있었다.