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Community Patterning of Benthic Macroinvertebrates in Slightly and Moderately Polluted Streams in Spring and Summer

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Benthic macroinvertebrates were collected two times from 116 sites at the 1st ~ 4th order streams in forest areas in Gyungsang province in late spring and late summer. The sample sites belonged to slightly and moderately polluted states. When communities were classified by the Self-Organizing Map (SOM), the gradient was observed according to degree of pollution. Within clusters of slightly polluted sites, however, seasonality was further observed. Scrapers, gatherer-collectors, and filterer-collectors were abundantly observed in late spring while shredders appeared more in late summer. The number of predator species increased in late summer. Behavior types were mostly clingers in two seasons. Community compositions at the moderately polluted sites were not much differentiated in different seasons. Gatherer-collectors and burrowers were dominantly collected in both seasons.

Key words : self-organizing mapping, community indices, water quality, species richness, diversity

INTRODUCTION

Conservation of aquatic communities has been regarded as one of the utmost concerns in sustainable ecosystem management. Biological communities efficiently reveal ecosystem functions and are direct indicators of ecosystem health (Hellawell, 1986). Biological organisms convey the integrative and continuous characters of water quality and are considered as suitable indicators (Hawkes, 1979; Sladecek, 1979; Tittizer and Koth, 1979; Hellawell, 1986; Rosenberg and Resh, 1993; Allan, 1995). Among biological communities, benthic macroinvertebrates have been widely used for assessment of water quality in aquatic ecosystems. Based on taxanomic diversities, sedentariness in behaviors and long life cycles, benthic macroinvertebrates characteristically respond to the impact of pollution from the watershed areas (Hynes and Coleman, 1968; Resh and Rosenberg, 1984; Hellawell, 1986; Resh *et al.*, 1995; Barbour *et al.*, 1996).

Since Hynes and Coleman (1968) reported ecology of benthic macroinvertebrates, community responses to disturbances have been studied in numerous accounts including resource depression of stream herbivores (McAuliffe, 1984), hydrological disturbance (Thomson *et al.*, 2002), stress from drought (Bond *et al.*, 2008), and sediment effects (Svendson, 2009). Through rapid industrial development in Korea, monitoring ecological states in aquatic communities garnered special attention since 1980's (Yoon, 1988; Chon and Kwon, 1991). Benthic macroinvertebrates in streams regarding community structure, standing crop and water

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quality estimation have been studied in various river basins in Korea: Suyoung River (Chon and Kwon, 1991), Han River (Bae and Park, 1992; Bae and Yoon, 1993; Kwak *et al.*, 2002; Bae *et al.*, 2003a; Bae *et al.*, 2005), Nakdong River (Oh and Chon, 1991; Lee, 1994; Park and Park, 2000; Song *et al.*, 2007), Somjin River (Ra *et al.*, 1989; Cho *et al.*, 1993; Yoon *et al.*, 1998), Youngsan River (Ra *et al.*, 1991; Cho *et al.*, 1996a, b), Mankyong River (Kim, 1991), Tamjin River (Kim *et al.*, 1996), Kum River (Kim *et al.*, 1985) and Jae Ju River (Yoon *et al.*, 1984). Benthic macroinvertebrate communities have been also surveyed at the polluted streams including the Suyong (Kwon and Chon, 1991; Youn and Chon, 1999; Park *et al.*, 2001; Song *et al.*, 2005), Masan (Yoon *et al.*, 1985), and Han River (Kwak *et al.*, 2002; Bae *et al.*, 2005) basins in southern Korea.

Although numerous accounts of studies have been reported, seasonal differences in community compositions of benthic macroinvertebrate have not been extensively reported. Drift phenomenon of macroinvertebrates in flooding seasons were investigated by Oh and Chon (1993), and spatial and temporal variation of macroinvertebrates were discussed regarding effects of flooding and drought by Bae and Park (2009). In previous studies, however, the species-based, abundance patterns were not explicitly disclosed in seasonal development. We focused on how community composition would vary, especially between late spring and late summer in forest areas. Considering high diversity and sensitivity to disturbances, community compositions in forest areas are important for revealing structural properties in communities and for monitoring response to natural and anthropogenic impacts. Forest and mountainous areas occupy 78% of the southern peninsula of Korea and would play an important role in expressing ecosystem health in Korea. Since benthic communities were consecutively collected two times in two seasons in each sample site, investigation of seasonal patterning was possible late spring and late summer. We further investigated how seasonal patterning would be influenced by anthropogenic disturbances in slight to moderate pollution states in streams. For the purpose of analyzing complex community data, the Self-Organizing Mapping (SOM) was utilized for ordination and clustering of the sampled communities and environmental data.

METERIALS AND METHODS

1. Sampling

As a project of National Natural Environment Monitoring supported by Ministry of Environment in Korea, benthic macroinvertebrates were collected in forest areas (altitude; 40 ~ 550 m) in Gyungsang province and were surveyed at the same sites two times, late spring (April ~ June) and late summer (August ~ September), in each year from 1998 to 2002. Two seasons were selected to reflect overall status of communities in relation with other taxa surveyed in Korea for the project. The surveys were conducted at 116 sites in 30 streams (1st ~ 4th order) in the area of Changyoung, Gosung, Sachun, Sunsan, Kimcheon, Kyoungju, Gumi, Sangju, Yangsan in the Nakdong River basin (Fig. 1). The benthic macroinvertebrate were collected by using a Surber sampler (30 cm × 30 cm, mesh size: 0.5 mm). The number of collected individuals

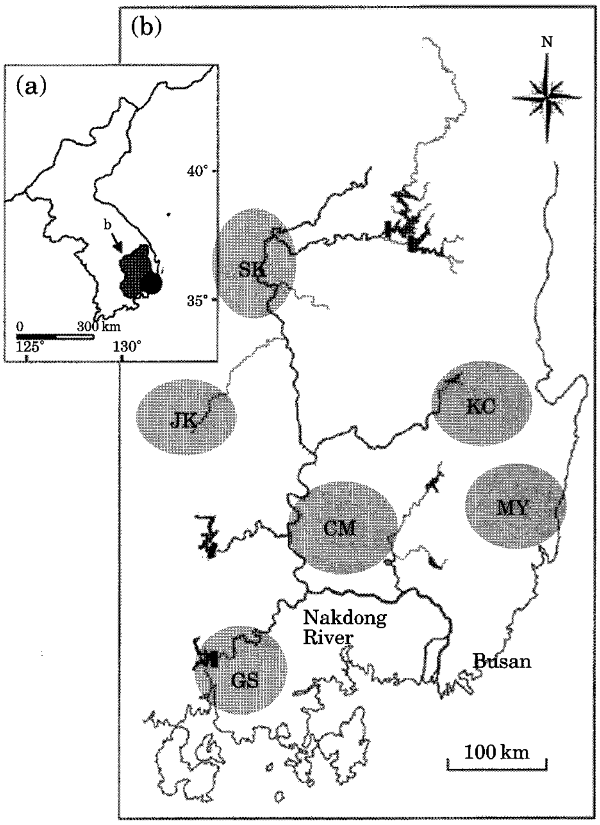


Fig. 1. Sampling areas for collecting benthic macroinvertebrates in streams in Gyungsang province in Korea.

Table 1. Environmental factors (mean ± SD), community data, and biological indices in different sample areas.

Sites	n	Abundance	Number of species	Conductivity (μs cm^{-1})	Turbidity (NTU)	BMWP	EPT (%)	Diversity	Dominance (%)	Altitude (m)	Temperature (°C)		Precipitation (mm)	
											Spring	Late summer	Spring	Late summer
CM	36	32729.6	108	132.0 (±90.4)	1.6 (±0.9)	34.8 (±15.4)	17.4 (±9.4)	2.43 (±0.56)	63.0 (±14.0)	177.6 (±165.8)	18.7	19.9	124.2	26.8
GS	56	34643.1	123	64.4 (±35.8)	8.0 (±9.8)	37.3 (±18.0)	19.5 (±13.6)	2.61 (±0.70)	61.2 (±16.1)	111.1 (±63.7)	21.4	25.1	201.1	296.7
SK	40	18733.1	99	67.9 (±33.3)	5.5 (±7.6)	45.4 (±25.1)	26.2 (±17.1)	2.61 (±0.78)	56.5 (±18.6)	201.0 (±88.4)	24	23.5	32.5	230.5
KC	44	27590.9	125	38.6 (±11.6)	0.4 (±0.3)	87.6 (±30.0)	33.7 (±14.0)	2.94 (±0.66)	55.8 (±16.7)	344.5 (±103.9)	15.4	25.2	7.4	75.6
JK	20	26606.7	115	70.8 (±23.4)	0.8 (±0.8)	89.8 (±23.9)	33.6 (±14.2)	2.65 (±0.66)	63.1 (±17.8)	234.0 (±102.1)	15.1	23.7	12	55
MY	36	19750.6	88	70.9 (±44.9)	6.8 (±21.4)	54.9 (±20.0)	30.0 (±12.4)	2.13 (±0.76)	70.0 (±16.8)	182.0 (±110.8)	13.8	24.1	66.5	416.2

was converted to the unit area (1 m^2).

The sample sites were slightly to moderately polluted. According to Mason (2002), the "clean but slightly impacted" sites are defined with the BMWP (Hawkes, 1997) values between 70 and 100, and "moderately impacted" with the BMWP values between 40 and 69. A small number of sample sites were below 40 in BMWP (i.e., polluted) in our study across the different sample areas. Since the number of sample sites was small and pollution states were not severe, those polluted sites were included into the moderately polluted sites. Environmental factors, biological data and sampling year for the sampling areas were presented in Table 1. Altitude was measured according to the map in the scale of 1 : 25,000. Rainfall at the sample area was recorded according to Korea Meteorological Administration during the survey period. Conductivity (μs cm^{-1}, ©1996 ORION Research. Inc. model 230A), turbidity (DRT100b, Shaban MFG inc.®) and temperature were concurrently measured *in situ*. The other methods for sampling and environmental measurements followed the National Natural Environment Monitoring protocol (Ministry of Environment, 1997) in Korea.

2. Classification and biological indices

In most cases the specimens were identified to species or to the lowest possible taxonomical level by following the keys for general taxa (Pennak, 1978; Brigham *et al.*, 1982; Merritt and Cummins, 1996; Yoon, 1998), Chironomidae (Wiederholm, 1983, 1986; Merritt and Cummins, 1996), Oligochaeta (Brigham *et al.*, 1982; Brinkhurst, 1986), and Trichoptera (Wiggins, 1996). The specimens were preserved in 7% formalin in the laboratory.

After classification of specimens species diversity (H') was obtained according to Shannon index (Shannon and Weaver, 1949):

$$H' = -\sum_{i=1}^{S}(P_i \ln P_i) \tag{1}$$

where p_i is proportion of the number individuals of the i th species to the total number of individuals, S is the total number of species, and *ln* is the logarithm (with the base number 2 in this case). Dominance index (D) was measured as (McNaughton, 1967):

$$D = n_1 + n_2 / \sum_{i=1}^{S} n_i \tag{2}$$

where n_i is the number individuals of the i th dominant species, and S is the total number of species. EPT richness (%) and the revised BMWP (Hawkes, 1997) were also obtained to indicate biological water quality.

3. Data analysis

Community data are complex and difficult to analyze since numerous species vary in nonlinear fashion in spatio-temporal domain. The Self-Organizing Map (SOM) based on the Kohonen network (Kohonen, 1989) efficiently mines complex data through unsupervised learning and has been considered an efficient classifier of communities in ecology for clustering and classification of communities groups (e.g., Chon *et al.*, 1996; Levine *et al.*, 1996; Chon *et al.*, 2000a; Kwak *et al.*, 2000; Park *et al.*, 2004; Song *et al.*, 2007). In the SOM, the output layer consists of $L \times M$ computation nodes in the SOM. With each neuron being represented as j, the output layer is arranged in two dimensions for convenience of visual understanding. Suppose a community data containing S species, and the density of species, i, is expressed as a vector x_i. The vector, x_i is considered to be an input layer to the SOM. In the network each node, j, is connected to each node, i, of the input layer. The connectivity is represented as the weights, $w_{ij}(t)$, adaptively changing in each iteration of calculation, t. Initially, the weight is randomly assigned in small values. Each neuron of the network computes the summed distance between the weights and the distance $d_j(t)$ at output node j network is calculated as shown below:

$$d_j(t)=\sum_{i=0}^{S-1}(x_i-w_{ij}(t))^2 \tag{3}$$

Input data matrix was formed with 241 variables (species) and 232 cases (sample units) based on benthic macroinvertbrates collected at the sample sites. The input values with greatly different numerical values in densities are avoided for training. The data were transformed by natural logarithm in order to emphasize the differences in low densities. Subsequently the transformed data were proportionally normalized between 0 and 1 in the range of the maximum and minimum density for each species collected during the survey period.

The neuron responding maximally to a given input vector is chosen to be the winning neuron, the weight vector of which has the shortest distance to the input vector. The winning neuron and possibly its neighboring neurons are allowed to learn by changing the connecting weights in the manner to further reduce the distance between the weight and the input vector as shown below:

$$w_{ij}(t+1)=w_{ij}(t)+a(t)(x_i-w_{ij}(t))Z_j \tag{4}$$

where Z_j is assigned to 1 for the winning (and its neighboring) neuron(s) while it is assigned 0 for the rest neurons, and $a(t)$ denotes the fractional increment of the correction. Detailed algorithm could be referred to Zurada (1992), Chon *et al.* (1996). After training, the Ward's linkage method (Ward, 1963) was applied to the weights of the SOM for clustering the patterned nodes. Training and clustering were carried out under the MAT LAB 6.1 environment (The Mathworks Inc., 2009).

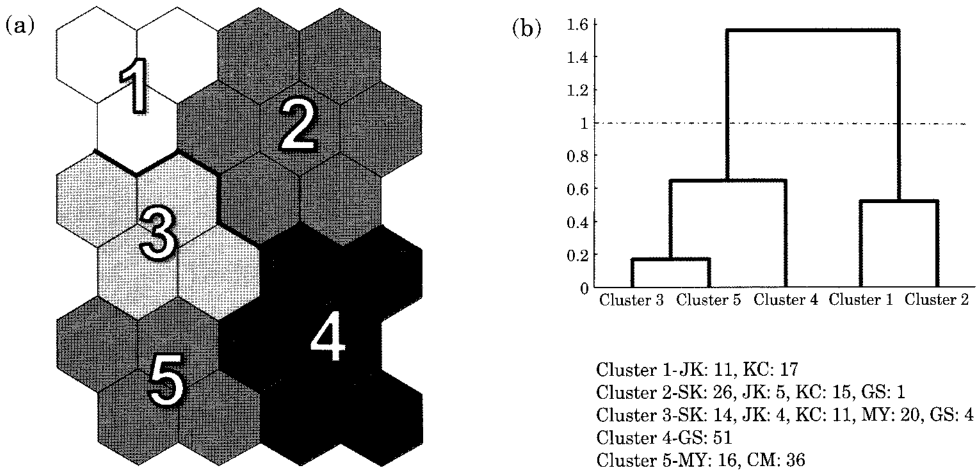
RESULTS

1. Overall community composition

In total 281 species were collected with average species richness of 14.8 and with average density of 582 individuals (ind.) m^{-2} during the survey period. The abundant Orders were Ephemeroptera (168 ind. m^{-2}; 28.87%), Diptera (167 ind. m^{-2}; 28.75%), Trichoptera (61 ind. m^{-2}; 10.43%) and Plecoptera (14 ind. m^{-2}; 2.38%). The dominant taxa included Chronomidae sp. and *Gammarus* sp. showing more than 10,000 ind. m^{-2} in total during the survey period. Twenty one species including *Baetis* Kua, *Cheumatopsyche brevilineata* and *Oligochaetae* sp. were collected with more than 1,000 ind. m^{-2}. Fifty six species including *Cincticostella castanea*, *Lethocerus deyrollei* and *Isoperla* Kua, however, were rare and occurred with less than 10 ind. m^{-2} in total during the survey period.

2. Patterning by the SOM

Benthic macroinvertebrate communities were clustered by the SOM (Fig. 2a), and were divided into two main groups based on the dendrogram of the Ward's linkage method (Fig. 2b). The clusters were arranged in the vertical gradient according to level of pollution. The communities collected from the slightly polluted sites were located in the upper area of the map while communities



Cluster 1-JK: 11, KC: 17
Cluster 2-SK: 26, JK: 5, KC: 15, GS: 1
Cluster 3-SK: 14, JK: 4, KC: 11, MY: 20, GS: 4
Cluster 4-GS: 51
Cluster 5-MY: 16, CM: 36

Fig. 2. Clustering of benthic macroinvertebrate communities on the SOM. (a) clusters with sample sites, and (b) the dendrogram of clustering according to the Ward's linkage method.

from the moderately polluted sites were placed in the lower area (Fig. 2a). The levels of water quality and community indices such as BMWP, EPT richness (%), and diversity were higher in the clusters located in the upper area of the SOM (Fig. 3). Conductivity and turbidity, in contrast, were higher in the lower group.

Clusters within the groups were further differentiated according to water quality indices and environmental factors (Figs. 2 and 3). Based on biological indices, cluster 1 was least polluted, being followed by cluster 2 in the upper group on the map. Conductivity was severely high in cluster 5 in the lower group of the map, indicating that cluster 5 belonged to the most polluted group in this study. Altitude was associated with water quality indices (Fig. 3c). In the lower group with high pollution level, altitudes were correspondingly low.

Rainfall was higher in the lower group and the level of precipitation was further differentiated to clusters 3, 4 and 5. Precipitation was different in different periods of rainfall before sampling (Fig. 3a, b). When precipitation was recorded within 7 days before sampling, rainfall was substantially high in cluster 4 (Fig. 3a). When the pre-rainfall period was increased to 1 month, however, amount of rainfall in clusters 3 and 5 also substantially increased (Fig. 3b).

The water quality was estimated as slight to moderate polluted sites in different clusters. BMWP ranged 70 ~ 120 (median; 100) at the slightly polluted sites in cluster 1, and 50 ~ 100 (median; 70) at cluster 2 in the upper area. BMWP values were in the minimal range around 20 ~ 60 (median; 41) in clusters 3, 4 and 5 in the lower area of the map (Fig. 3).

3. Slightly polluted sites

Community data from the slightly polluted sites (clusters 1 and 2) in Fig. 1 were separately trained with the SOM (Fig. 4). The BMWP values of all sites were higher than 70. Communities were vertically divided into two groups according to seasons. In order to express seasonality on the SOM clustering, the binary value was assigned to different seasons: "0" to the samples collected in late spring and "10" to the samples collected in late summer. The average value of seasons was expressed on *Y* axis in Fig. 5a. Seasonality was clearly differentiated, minimal in clusters 1 and 2 (April ~ June) and maximal in clusters 3 and 4 (August ~ September).

Clusters 3 and 4 in the lower group were also characterized by high levels of precipitation when rainfall was recorded in one month before sampling (Fig. 5c). Precipitation in cluster 1 appeared to be also high (Fig. 5b) although the cluster belonged to the lower group (Fig. 5c). In this case, however, strong rainfall was concentrated at only two sites in the area of SK (Fig. 1). If these two sites are excluded, the level of rainfall was lower (2.7 ± 1.5 mm in a week, and 17.2 ± 12.0 mm in a month), being similar to the level shown in cluster 2 (Fig. 5c). If the period of pre-rainfall period was

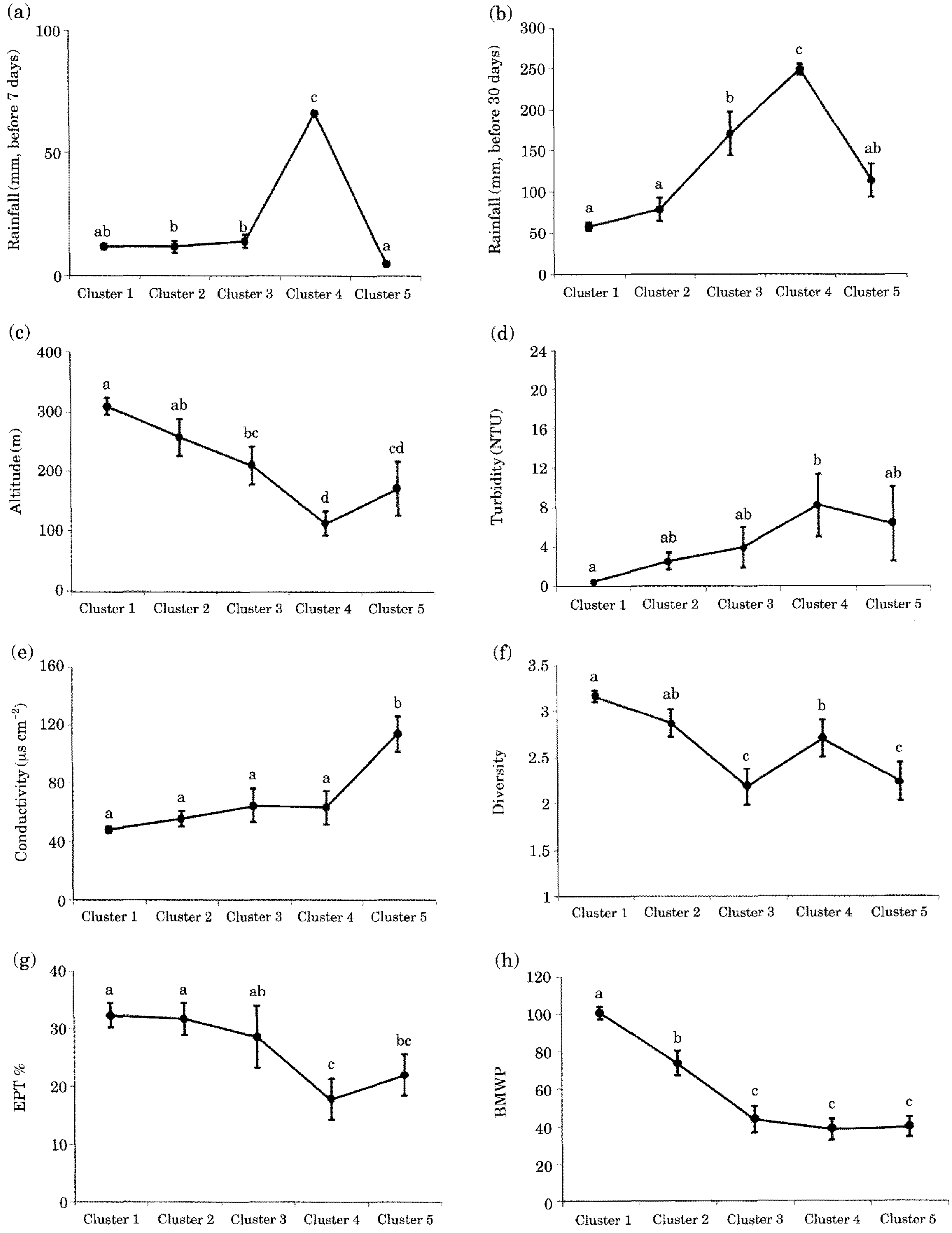
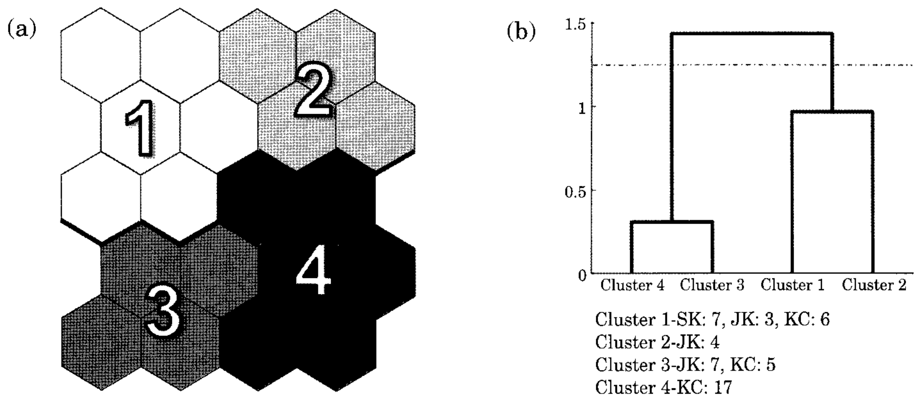


Fig. 3. Physico-chemical and biological indices in different clusters of SOM (Fig. 2). The vertical bars indicate standard errors. The different alphabets present significant difference according to the Tukey HSD test ($P < 0.05$).



Cluster 1-SK: 7, JK: 3, KC: 6
Cluster 2-JK: 4
Cluster 3-JK: 7, KC: 5
Cluster 4-KC: 17

Fig. 4. Clustering of benthic macroinvertebrate communities collected from the slightly polluted sites. (a) clusters with sample sites, and (b) the dendrogram of clustering according to the Ward's linkage method.

shortened to 1 week before sampling, precipitation was not significant in different seasons (Fig. 5b). Considering the precipitation was not high in both measurements (around 10 mm for 1 week and around 40 mm for 1 month) the amount of rainfall before sampling was considered to be low (Fig. 5a, b).

Biological indices such as diversity, EPT richness (%) and BMWP were overall high but were in the similar range among the clusters (Fig. 5). Fig. 6 shows species with higher seasonal difference in frequency (over 30%) and density (over 20 ind. m^{-2}). In late spring scrapers (*Epeorus curvatulus* and *Pteronarcys macra* Ra *et al.*), gatherer-collectors (*Uracanthella rufa* (Imanishi), *Paraleptophlebia chocorata* and *Choroterpes altioculus*) and a filterer-collector (*Hydropsyche* Kue) abundantly appeared. They mostly belonged to clingers (Fig. 6). One species in predator (*Rhyacophila shikotsuensis*) also appeared in late spring. In late summer, however, species composition changed substantially (Fig. 6). Shredders (*Taenionema* sp., *Micrasema* KUa and *Hydatophylax nigrovittatus* McLachlan) and predators (*Rhyacophila shikotsuensis*, *Neoperla quadrata* and *Parachauliodes continentalis*) were abundant. One species of scraper (*Psilotreta kisoensis* Iwata) was present in this season. The species were mostly clingers (*Rhyacophila shikotsuensis*, *Neoperla quadrata*, *Taenionema* sp., *Micrasema* KUa and *Parachauliodes continentalis*) and sprawlers (*Hydatophylax nigrovittatus* McLachlan and *Psilotreta kisoensis* Iwata) in late summer. One species of burrower (*Ephemera separigata*) was also collected in this season.

4. Moderately polluted sites

Communities at the moderately polluted sites (clustered in the lower area in Fig. 2a) were also separately clustered by the SOM (Fig. 7). Seasonality was less observed in this case (Fig. 8a). Communities were vertically grouped according to precipitation and conductivity (Fig. 8b, f). The sample sites with higher precipitation were grouped in the upper area of the SOM (Fig. 8b, c). The difference in precipitation was observed among clusters within 7 days before sample collection. Conductivity was exceptionally high in cluster 5 (Fig. 8). Biological indices were invariably low across the different clusters. Overall, the clusters were grouped according to pollution in the maximal range (cluster 5), and the groups with low precipitation (clusters 3 and 4) and with high precipitation (clusters 1 and 2).

Species compositions were variable in different groups of clusters (Fig. 9). At the polluted sites for cluster 5 and at the group of clusters 3 and 4 with low level of precipitation, differences in community compositions, however, were less distinctive in different seasons (Fig. 9) compared with the slightly polluted sites (Fig. 6). Among 103 species belonging to clusters 3 and 4 there was no species showing difference greater than 30% in frequency in different seasons. Instead species showing 20% difference in frequency and 20 ind. m^{-2} difference in density were listed in Fig. 9. In late spring *Semisulcospira tegulata*, *Oligochaeta* sp. and *Ephemera strigata* were abundant, while frequency of *Gammarus* sp. was higher in late summer. But densities of *Gammarus* were in the

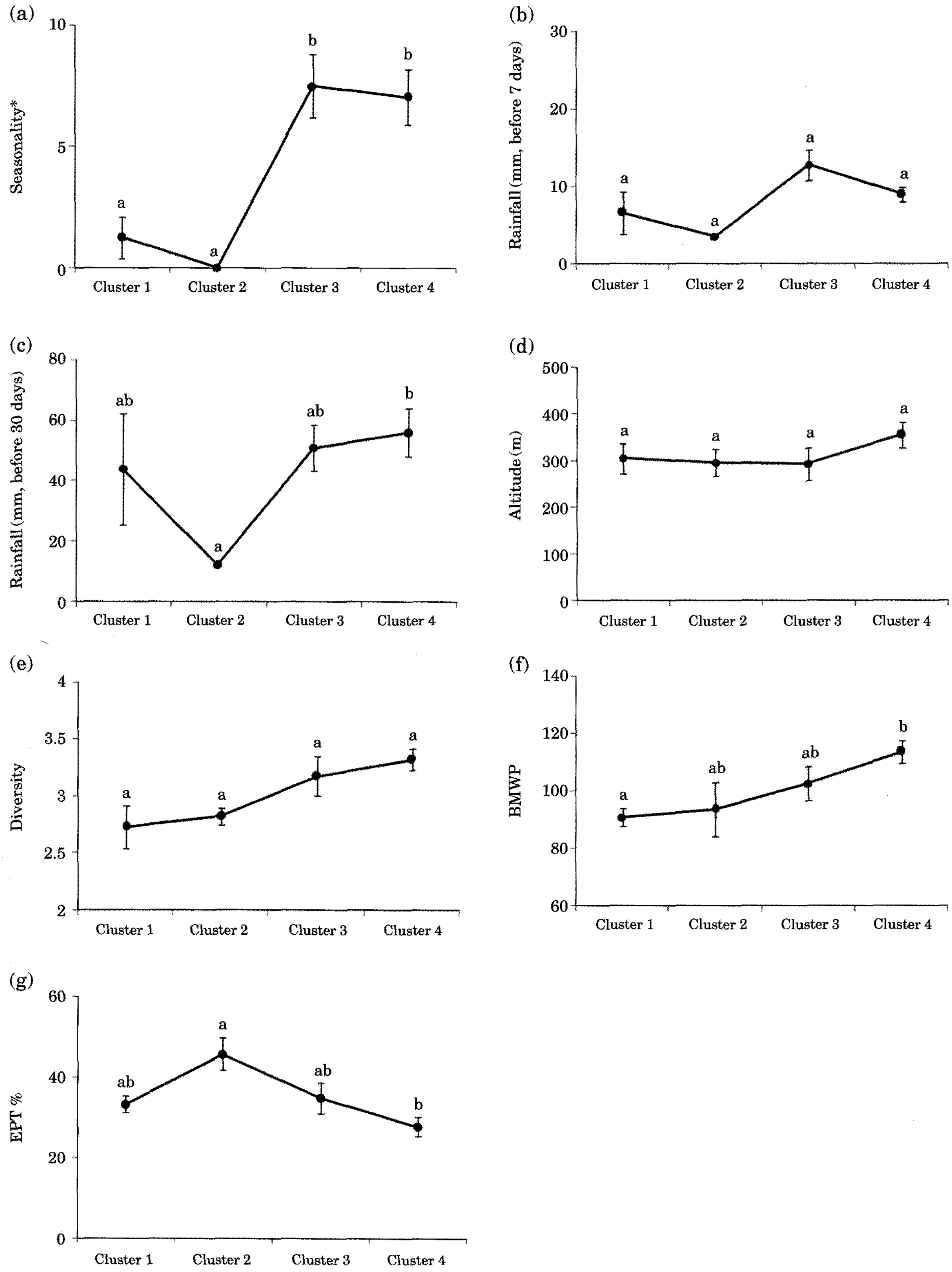


Fig. 5. Physico-chemical and biological indices in different clusters of SOM (Fig. 4). The vertical bars indicate standard errors. The different alphabets present significant difference according to the Tukey HSD test ($P<0.05$). *Score of seasons: late spring; 0, and late summer; 10.

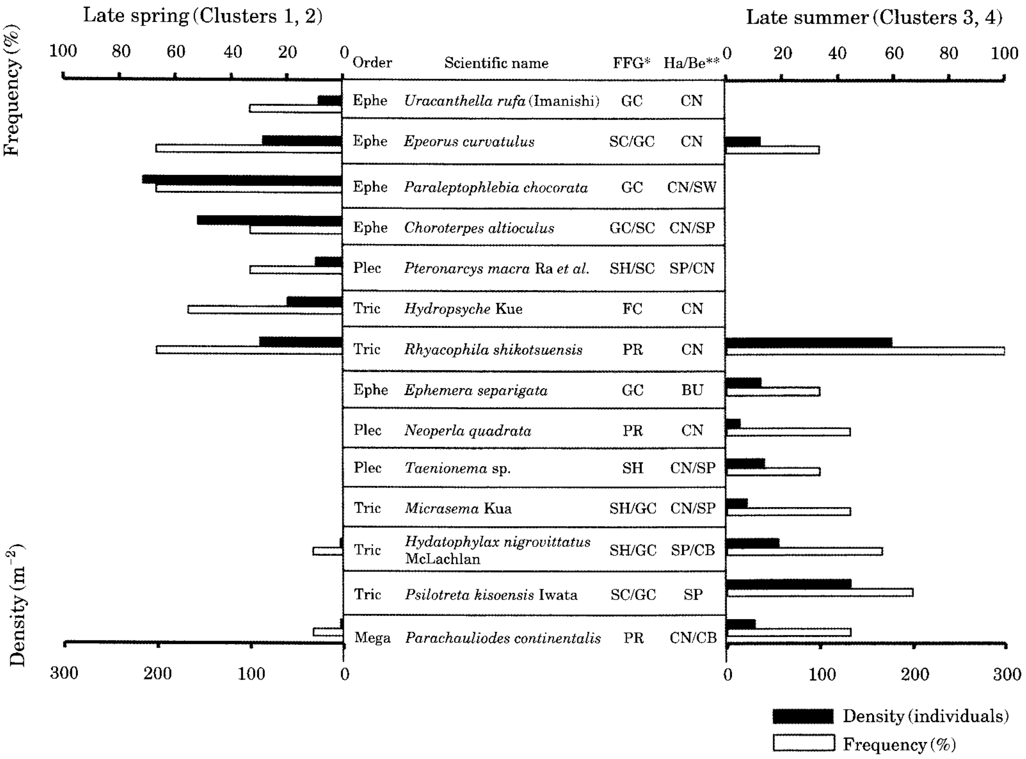


Fig. 6. Frequency and density of the selected species collected from the slightly polluted sites in spring and summer. FFG* (Functional Feeding Group): PR; predator, GC; gatherer/collector, FC; filterer/collector, SC; scraper, and SH; shredder. Ha/Be** (Habitat and Behavior): CN; clinger, CB; climber, SP; sprawler, BU; burrower, and SW; swimmer.

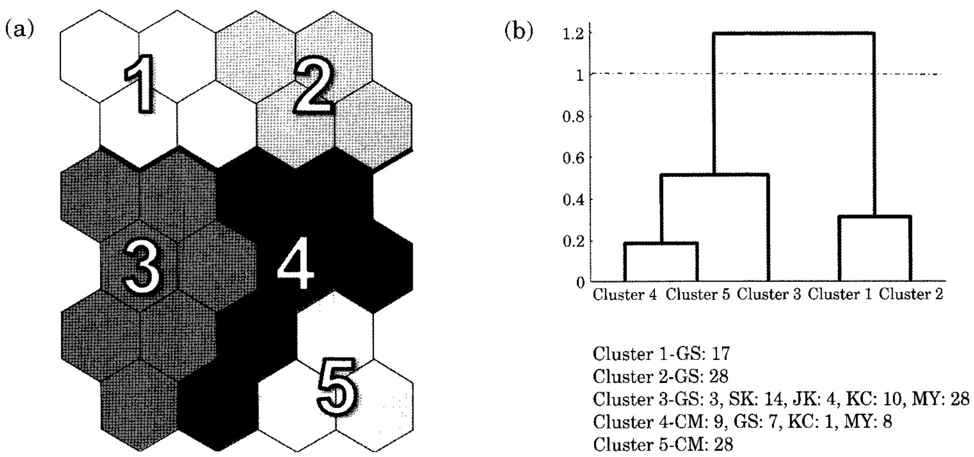


Fig. 7. Clustering benthic macroinvertebrate communities of the moderately polluted sites. (a) clusters with sample sites, and (b) the dendrogram of clustering according to the Ward's linkage method.

similar range in two seasons. Scraper/gatherer-collectors (*Beatis* nla, *Beatis* KUa and *Choroterpes altioculus*), gatherer-collectors (*Ephemera strigata* and *Ephemera orientalis*), a predator (*Davidius lunatus*) and a scraper (*Koreanomelania paucicincta*) appeared in both seasons.

In cluster 5, difference in community composition was minimal. The total number of species presented in cluster 5 was 36. Most of species were tolerant to organic pollution. A few species selectively tolerant to pollution (e.g., tubificids, leeches and chironomids) were dominant in pollut-

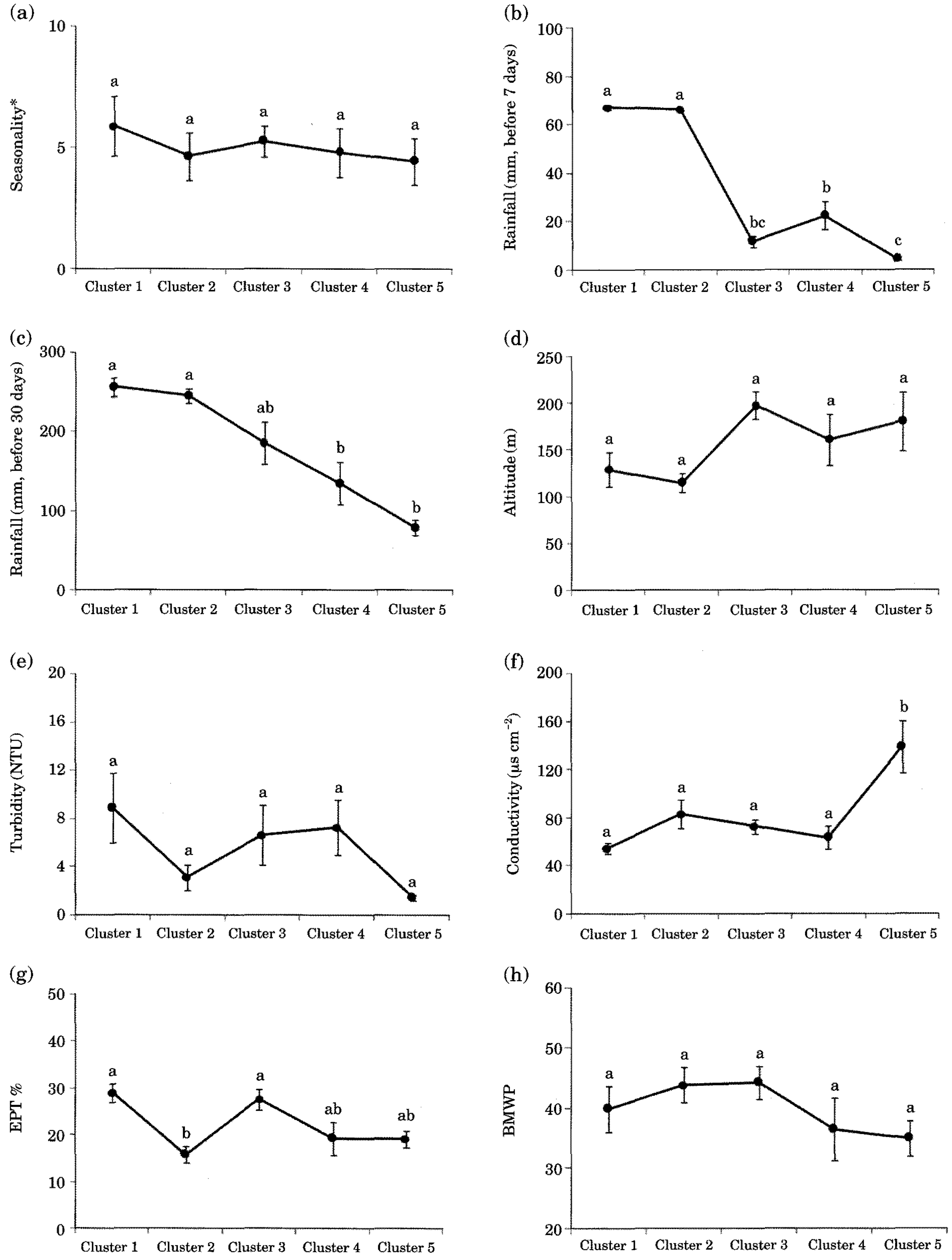
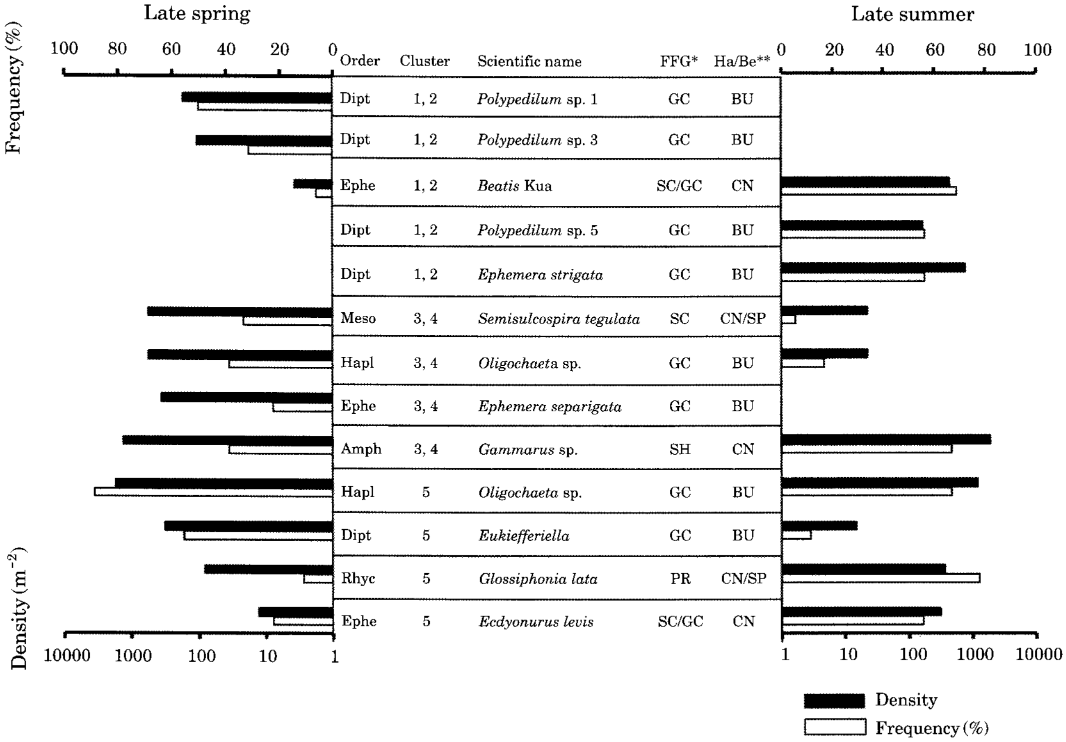


Fig. 8. Physico-chemical and biological indices in different clusters of SOM (Fig. 7). The vertical bars indicate standard errors. The different alphabets present significant difference according to the Tukey HSD test ($P < 0.05$). *Score of seasons: late spring; 0 and late summer; 10.



Order	Cluster	Scientific name	FFG*	Ha/Be**
Dipt	1, 2	*Polypedilum* sp. 1	GC	BU
Dipt	1, 2	*Polypedilum* sp. 3	GC	BU
Ephe	1, 2	*Beatis* Kua	SC/GC	CN
Dipt	1, 2	*Polypedilum* sp. 5	GC	BU
Dipt	1, 2	*Ephemera strigata*	GC	BU
Meso	3, 4	*Semisulcospira tegulata*	SC	CN/SP
Hapl	3, 4	*Oligochaeta* sp.	GC	BU
Ephe	3, 4	*Ephemera separigata*	GC	BU
Amph	3, 4	*Gammarus* sp.	SH	CN
Hapl	5	*Oligochaeta* sp.	GC	BU
Dipt	5	*Eukiefferiella*	GC	BU
Rhyc	5	*Glossiphonia lata*	PR	CN/SP
Ephe	5	*Ecdyonurus levis*	SC/GC	CN

Fig. 9. Frequency and density of taxa for groups with high (cluster 1 and 2) and low (cluster 3 and 4) precipitation and with high level of pollution (cluster 5) according to the SOM (Fig. 7). FFG* (Functional Feeding Group): PR; predator, GC; gatherer/collector, FC; filterer/collector, SC; scraper, and SH; shredder. Ha/Be** (Habitat and Behavior): CN; clinger, CB; climber, SP; sprawler, BU; burrower and, SW; swimmer.

ed streams (Hellawell, 1986; Qu *et al.*, 2008; Tang *et al.*, 2010). The species showing 20% difference of frequency in different seasons were *Oligochaeta* sp., *Eukiefferiella*, *Glossiphonia lata* and *Ecdyonurus levis*. Although density differences were observed in this species, frequency was similarly high in different seasons (Fig. 9). Scrapers (*Physa acuta*, *Radix auricularia coreana*, *Parafossarulus manchouricus*, *Semisulcospira tegulata* and *Koreanomelania paucicincta*), scraper-gatherer collectors (*Beatis* KUa and *Heptagenia kihada*), filterer-collectors (*Macronema radiatum* and *Aethaloptera* KUa), gatherer-collectors (Chironomidae sp., *Rheocricotopus* and *Atyidae* sp.) and a predator (*Tanypus*) were collected in common in both seasons. Functional feeding groups and behavior types, however, were different in different seasons. In late spring *Oligochaeta* sp. and *Eukiefferiella* were dominant. They were a gatherer-collector and a burrower, respectively. In late summer a predator *Glossiphonia lata* and a scraper/gatherer-collector *Ecdyonurus levis* were abundant. Behavior types, however, were similar in different seasons. All species were mainly clingers.

In clusters 1 and 2 with high precipitation most samples were selectively collected from the area of GS (Fig. 1). Scraper/gatherers-collector (*Epeorus latifolium*, *Beatis* nla and *Heptagenia kihada*), gatherer-collector (Chironomidae sp., *Tanytarsus* and *Tubifex tubifex*) and predators (*Conchapelopia melanops* and *Glossiphonia lata*) were present in both seasons. Differences in community compositions were observed in different seasons (Fig. 8a, c). Among 66 species belonging to cluster 1 and 2, 8 species showed differences in frequency higher than 20% (Appendix 1), while 5 species were different in density higher than 30 ind. m^{-2} (Fig. 9). In late spring *Polypedilum* sp.1 and *Polypedilum* sp.3 were dominant while *Ephemera strigata, Polypedilum* sp.5 and *Beatis* Kua were abundant in late summer. FFGs were not considerably different between different seasons in clusters 1 and 2, including scrapers and gatherer-collectors in common. Burrowers and a clinger were also present in late summer.

DISCUSSION

Community variation in seasonal development (late spring and late summer) was demonstrated in different levels of pollution in forest areas. The overall gradient was first observed according to pollution level (Fig. 2). Although the sample sites did not cover the severely polluted state, only slight to moderate polluted states were sufficient in influencing change in community structure, overriding variation due to seasonality (Figs. 2 and 3). This confirmed the previous studies (Chon *et al.*, 1991; Song *et al.*, 2007) reporting strong anthropogenic effects on community structure. The previous reports, however, covered the severely polluted sites. This study only included the pollution level up to moderate level and confirmed that even the moderate pollution would be still influencing in disturbing natural community compositions.

When variation in community data was further disclosed within the slightly polluted sites, difference in community compositions, however, was detectable due to seasonality. Scrapers and gatherer-collectors in late spring changed to shredders in late summer (Fig. 6). This indicated that the leaves from the canopies started to fall into streams in this season and served as food sources for shredders. Consequently a higher number of species in predators occurred to catch the shredders and other types of macroinvertebrates in late summer. This information regarding FFG would be important for characterizing community structure and for monitoring biodiversity in the streams.

Effects of direct precipitation were not influential in community compositions in this study. At slightly polluted sites precipitation before sampling was low by showing 3 mm in spring and 17 mm in summer (excluding two sites with high precipitation in cluster 1 in Fig. 5c). Consequently the impact of rainfall was not observable in community composition. In communities for the clusters represented by moderately pollution and high precipitation (cluster 1, 2 in Fig. 7), effects of precipitation were less observed. Although overall precipitation levels were somewhat higher, differences in precipitation in different seasons were minimal since the amount of rainfall was similar in two seasons, with 62 mm in spring and 70 mm in fall. The communities may have been already somewhat influenced by rainfall before sampling in late spring and similarly in late summer. However, the low amount of rainfall in these seasons would not affect community structure greatly. According to Tikkanen (1994) communities would almost completely recover from the slight disturbances such as rainfalls observed in this study within eight days.

In addition to rainfalls in the pre-sampling periods, effects of flooding in summer due to the Monsoon climate were neither clearly observed in this study. Flooding indeed occurred in late July with 794.4±273.7 mm during the survey period. However, the impact of flooding was not observable in community compositions collected in late summer. Since sampling was conducted in late August or mostly in September, at least 50 days passed after rainfall before sampling. Communities appeared to recover at the time of sampling based on community compositions observed in this study (Figs. 6 and 9). According to Fisher *et al.* (1982) and Molles (1985) instantaneous flooding would decrease 94~98% of densities of macroinvertebrates. Biomass and density would return to 50% of the original level in 13 days and 35 days, respectively. Biomass and diversity would recover almost completely approximately 60 days after flooding. Our study confirmed that communities would recover from flooding when sampling was conducted at least 50 days after flooding. Seasonality, however, was still observed in late summer after recovery. Abundance in Ephemeroptera belonging to gatherer-collector and scraper decreased at the sites with slight pollution in late summer (Fig. 6). In contrast shredders in Trichoptera and Plecoptera increased in densities in this season. The changes in community composition may be due to life cycles in this season and provision of food source in the sampling areas, but need to be further studied in the future regarding seasonal development of communities.

Communities of benthic macroinvertebrates were reported to be dependent upon geomorphological conditions in streams (Park *et al.*, 2007). In this study, however, the effects of altitudes and other geomorphological conditions were not considered since the sampling area was somewhat limited in Gyungsang province and the altitudes were not highly variable (Fig. 3a). Altitudes appeared to be associated with the pollution levels in the study (Fig. 3c, e), implying that the lower areas were closer to the city and industrial areas and were influenced by anthropogenic disturbances.

Also two seasons were selectively surveyed for this study. In order to fully characterize community compositions in temperate zones four seasons would be more suitable (Bae and Park, 2009). Surveys covering the spatial and temporal effects need to be conducted in larger scale in four seasons in the future.

In conclusion the sampled benthic macroinvertebrates in forest areas were sensitive to pollution states even in the moderately level and overrided variation due to seasonal effects. When community data from the slightly polluted sites were separately analyzed, however, seasonality appeared in community compositions. FFG of scraper/gatherer-collector in late spring accordingly changed to shredders in late summer. At polluted sites seasonal effects were not greatly observed and community compositions were not much differentiated compared with the case of the slightly polluted sites. Direct effects of precipitation, either due to pre-rainfall before sampling or flooding, were not clearly detected in community compositions in this study, while overall seasonal differences were observed after recovery of flooding in two seasons. Patterning of communities in different seasons would be useful in revealing community structure, monitoring environmental impact, and providing information on maintenance of biodiversity in streams.

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