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Change of Benthic Macroinvertebrates Community in the Yongmoonchun, Yang Pyong

Jin, Jae-Ho and Young-Deuk Rim*
*Incheon Sunhak Elementary School, Incheon National University of Education**

용문천 저서성 대형무척추동물 군집의 변화

진 재 호 · 임 영 득*
인천선학초등학교, 인천교육대학교*

ABSTRACT

There are 7 classes, 17 orders, and 141 species of benthic macroinvertebrates at the 5 study sites from Feb. '91 to May, '92. Total species frequency number has less variations among sites than seasonal changes. Not considering seasonal changes this indicates that there are some influences from outside pollution sources. Seasonally, Ortho chadiinae sp. 2 take 21.2% share of total species. It was the dominant species in Feb. '9l. With total average level Ephemeroptera take 5l. 3% of total species as first dominant species, Diptera 27.8% as second dominant species and Trichoptera 16.7% as third dominant species. Through these biological indexes, they appear to have unstable living environments in summer at sites 1 and 5. One can see that site 1 is more polluted than site 3 because site 1 has more pollution sources such as pastures and recreation areas.

Key words: Benthic macroinvertebrates, Yongmoonchun, Biological index.

INTRODUCTION

There have been numerous reports that indicate close relationships between the changes in human habitats, natural ecosystems and an increase in human populations.

The freshwater ecosystems would be the most sensitive to environmental changes caused by human factors among natural ecosystems (Davis 1973). The community of freshwater ecosystems consist of algae, aquatic plants, fish, insects, crustacea, etc. Among them, benthic macroinvertebrates, serving as primary or secondary consumers in freshwater ecosystems, became food sources for the higher animals such as the fish. They also are very valuable in evaluating environmental conditions because they tend to react sensitively to the influences of a foreign substance coming into water and select the most favorable locations to survive. The majority of benthic macroinvertebrates are aquatic insects. They tend to live in limited areas and are easy to collect quantitatively. It is why they have been used successfully in ecological studies (Hilsenhoff 1987, Quinn and Christoper 1990). Aquatic insects have been used effectively as biological indicators to determine environmental conditions of stream ecology (Hynes 1960, Wilhm 1972). They are very sensitive to the environmental changes and show definite different endurance ranges to the changes depending upon species.

In Korea, several reports indicate that the structure of benthic macroinvertebrate communities have been studied since the late 1960's. Many scholars have tried to determine water quality biologically by means of analyzing the benthic macroinvertebrate community. They have fully studied them in most major rivers throughout the southern part of the Korean peninsula as well as most islands, including Cheju island. There are several reports that have studied benthic macroinvertebrates in the Han river including tributaries (Yoon *et al.* 1985, Kim *et al.* 1979, Yoon *et al.* 1989, Yoon *et al.* 1990, Yoon *et al.* 1993).

It is our intention to supply basic data to understand stream ecology by means of analyzing the community and to study the effects of seasonal and physicochemical factors to the community of Yongmoonchun.

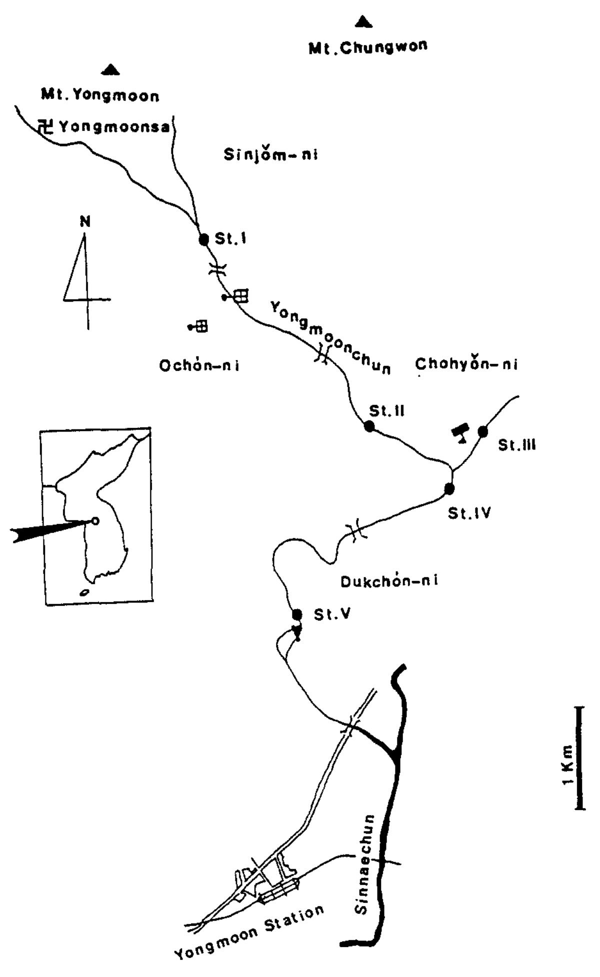

Fig. 1. The map of studied area from the upper stream of Mt. Yongmoon during Feb. 1991-May. 1992.

MATERIAL AND METHODS

Site description

This study was carried out from Feb. 1991 to May. 1992 with 6 field trips as follows: Feb. 9. 1991, July 14, 1991, Sept. 20, 1991, Dec. 1, 1991, Mar. 22, 1992, and May 17, 1992. Five sampling sites were chosen from the upper stream of Yongmoon Temple to down towards Yongmoon Train Station.

Site 1 : Most of the upper creek located at 1 Km down from Yongmoon Temple. One side has a little rolling hill and the other side has around 3 m bank with a slight slope. Sometimes both sides lie under a shade because of the heavy brushes. A near by farm is suspected to be a source of contamination especially when people visit heavily. In the creek, there are large rocks standing above the water surface and lots of big pebbles in creek beds change heavily depending upon water volumes. The creek has a width of approximately 10~20 m, length of 6~7.5 m and depth of 20~43 cm. The deepest point is 1.5 m and the water flows fast with 1.2 m/sec. velocity.

Site 2 : Located at 2.5 Km down from site 1 the creek has a width of 25~33 m and length of 12~20 m. The lowest water depth is 15~26 cm and the slowest velocity 0.4~0.6 m/sec. among the sites. One side has a road with light traffic, and the other side has a rice paddie fully exposed to the environment. Creek beds consist mainly of large gravels and sand. There is no differences among sites in depth. Mesogasropoda and Basommatophora are dominant species and there are not much seasonal changes of creek bed structures. The phenomena of slow water velocity is due to the rocks and gravels of upper creek.

Site 3 : Placed at the point 70 m from the main gate of Chohoyn Elementary school, there are rice paddie on both sides at a to degree angle. Sewer lines are connected to the houses at 40 m from the upper creek sampling sites. Water velocity is 0.6 m/sec, and water volume does not show much differences seasonally. Small gravels are main part of the water bed and lots of rocks, 30~50 cm in diameter, are scattered 10 m from the upper creek down to the sampling site. The creek had a depth of 17.5~36 cm and a width of 6.7~11.4 m at the last field trip. It showed high turbidity due to rice seedlings transfered to rice pads. There are lots of small gravel sliding down to the lower places due to several rainfalls. Water volumes are increased in whole with no differences at slow-flowing points.

Site 4 : Located at 150 m down from the junction of site 2 and 3. Both sides of creeks have banks surrounded by open environments. There are lots of weeds and shrubs growing on the creek beds with no water flows. Creek shows 50~120 cm in water depth from the junction to 50 m down from the point. Water and gravel hit each other down to 40 m from the junction. Creek is 40 m wide, 6.3~15.3 m at length and 23.5~36 cm in depth. In general, there are different water velocities due to different channel widths. Sampling sites are chosen at the fastest flowing point in velocity (1.2 m/sec.) and the lowest point in depth. This is applied to all sampling sites.

Site 5 : One side has hills, 100 m in height, and the other side has a rice paddy. There is a bridge at 150 m upstream from sampling site and a training camp at 200 m also from the site. Creek has a width of 50~70 m, length of 5~20 m and a depth of 19.5~33 cm. Water bed mainly consists of gravel and some rocks: 50~120 cm diameter and they are exposed above water level. 7~8 m downstream from the sampling site shows 100~150 cm in depth. From 20 m downstream, waterway becomes wider with 40~60 m in width and 30~50 cm in depth.

Methods

Sampling are carried out quantitatively as well as qualitatively. A hand net was used for qualitative samplings and a Suber net (50 × 50 cm) was used for quantitative samplings. The sampling was done two times at each site. Collected benthic macroinvertebrates were fixed with Kahle's Fluid (Edmund, 1976) in the field. Samples were moved to the laboratory and sorted qualitatively using lmm sieve and preserved in 80% alcohol. Fixed samples were sorted and counted. Environmental factors such as water temperature, pH, conductivity and dissolved oxygen (DO) were measured with Horiba water check U-7 in the creek.

RESULTS AND DISCUSSIONS

Environmental variables

Water temperatures show 0.8~26.1℃ during the study. Temperatures do not differ among sites in the winter, but it was rising higher toward the lower part of the creek during the summer. pH ranges were 5.2~7.6 and showed little differences among the sites. The significant pH difference were between site 3 (pH=5.2) and site 1 (pH=7.6) in March. DO ranges were 8.0~16.0 ppm at all sites during experimental periods. Site 1 shows the highest at 16.0 in Dec., '91 and the lowest DO at 8.1 in Mar. '92. Even if DO is influenced by water temperature, these results indicate that the affects of pollution sources were varying by the seasonal changes, because site 1 is located at next to a recreational ground.

Benthic community

The benthic macroinvertebrates showed are 7 classes, 17 orders and 141 species during the study. These consists 2 species of Nematoda, 1 species of Planaria, 1 species of Oligochaeta, 2 species of Hirudinea, 3 species of Gastropoda, 1 species of Crustacea and 131 species of Insecta. The Insectas were classified as follows:

- Order Ephemeroptera : 9 family, 20 genus, 34 species
- Order Trichoptera : 12 family, 19 genus, 31 species

Table 1. Environmental variables (water temperature, pH, dissolved oxygen)

Item	Site \ Month	1991 Feb.	1991 July.	1991 Sep.	1991 Dec.	1992 Mar.	1992 May
W.T	1	1.5	18.0	19.8	5.5	10.2	14.0
	2	0.8	25.4	18.0	5.9	13.3	14.7
	3	2.0	23.2	21.7	6.0	12.4	13.8
	4	1.1	22.4	19.8	4.4	6.3	13.4
	5	1.1	26.1	18.7	3.5	5.9	13.5
pH	1	6.1	6.1	6.2	5.8	7.6	6.1
	2	6.2	6.2	6.1	6.1	7.2	6.2
	3	6.2	6.1	6.1	6.1	5.2	6.2
	4	6.3	6.2	6.4	6.2	6.8	6.1
	5	6.2	6.0	6.3	6.2	6.5	5.8
DO	1	15.7	11.4	8.1	16.0	9.1	9.6
	2	12.4	12.1	10.1	13.7	10.9	9.6
	3	12.5	13.5	9.2	13.2	12.3	10.1
	4	11.3	14.7	10.1	12.4	12.5	10.5
	5	13.2	10.6	9.8	14.6	8.0	10.3

- Order Diptera : 8 family, 12 genus, 29species (Except family Chironomidae)
- Order Coleoptera : 4 family, 12 genus, 13 species
- Order Plecoptera : 6 family, 9 genus, 10 species
- Order Odonata : 4 family, 8 genus, 9 species
- Order Megaloptera : 1 family, 2 genus, 2 species
- Order Lepidoptera : 1 family, 2 genus, 2 species
- Order Hemiptera : 1 family, 1 genus, 1 species

Seasonal changes of community structure

Total abundance of benthic community was highest in Dec. 1991 with 85 species and the least in July with 56 species. The total number of species checked show the most abundant at site 2 with 99 species and the poorest at sites 1 and 5 with 81 species. This indicates that there is not much difference in environmental conditions along the experimental sites, because species frequency number shows little difference among the sites. In terms of main creek's flowing direction, the total species frequency number decreased gradually except in site 1. Since sites 1 and 5 showed the same frequency number, this indicated that some pollutants were able to spill into the creek because of its location next to Mt. Yong Moon's recreation area. This group of classified organisms show a typical model of mountainous creeks that mainly consist of insects. While Ephemeroptera appeared evenly throughout all the sites, Trichoptera, Odonata and Diptera showed a high frequency number compared to other species at sites 2 and 3. This is because of the decreasing water velocity.

The seasonal change in number of species show large increases in fall than in spring. The total number of species increasing gradually during July, Sept. and Dec. in 1991. This indicates that heavy rainfalls and the leisure seasons are important factors influencing them. Decrease in species frequency number in July and Sept. in 1991 should be influenced by artificial factors such as pollutants from recreation areas, animal farms, and heavy rainfalls. Fig. 2 shows the composition of species frequency number during the experimental period at all sites of Mt. Yong Moon Creek. The general phenomenon is to have a high frequency number of Ephemeroptera (24.1%) and Trichoptera (22.0%) in the creek. This indicates pollution sources in the creek because Plecoptera has lower composition percentage(7.1%) than Diptera (20.

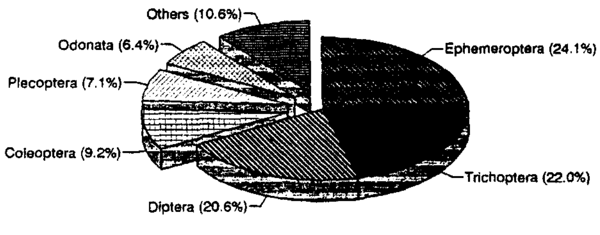

Fig. 2. Composition of species frequency number of major benthic macroinvertebrate taxa in the upper stream of Mt. Yongmun during February, 1991-May, 1992.

6%) and Coleoptera (9.2%). In fact, upper part of the creek is connected with Mt. Yong Moon's recreational area. Fig. 3 discloses the total number of main species at all experimental sites. While Ephemeroptera was counted evenly at all sites, Trichoptera and Diptera showed a high frequency number at site 2 and a low one at site 5. This indicates the unique characteristics of the area.

Calculations based on the number of species

There are wide ranges of abundance numbers such as 6,256 organisms/0.5 m^2 at site 1 and 10,225 organisms/0.5 m^2 at site 4 which is at conjunction of 2 creeks. Seasonally, wintertime and flooding time have a low abundance and Spring and Fall have a relatively high abundance number. The total number of organisms counted at all sites is 41,920 organisms/0.5 m^2 and average abundance number is 8, 384 organisms/0.5 m^2. Among them, the composition of Ephemeroptera is 51.3%, Diptera 27.8% and Trichoptera 16.7%. Contrary to the typical mountainous creek model, Diptera shows a high abundance number through all experimental sites. Site 1, located at the upper creek, shows a high abundance number of Diptera and Gastropoda which suggests the possibility of an influx of organic pollutants (Fig. 4). *Epeorus kibunensis*, *Serratella rufa*, *Epeorus latifolium* of Ephemeroptera, *Hydropsyche* KUb, *Hydropsyche* KUe of Trichoptera and Ortho chadiinae sp. 2, Chironomus sp. 1 of Diptera were counted more than other species with 2,000 organisms/0.5 m^2. With seasonal variation of species abundance number, Ephemeroptera started to increase in number from July before gradually increasing it's number with a significant increase after Dec. Diptera shows a drastic difference in abundance number between July peaking in Mar. Trichoptera shows a drastic decrease in July before gradually increasing its number between July and Sept., with the highest increase in Mar. If one disregards the seasonal changes with life cycle in Mt. Yong Moon Creek, it shows possibilities for improvement of water quality. This is because of the pollution resisting species have increased in early '91, with the number of non-resisting group increasing

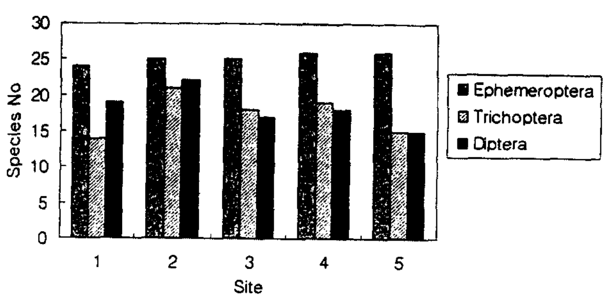

Fig. 3. Site variation of major taxa at Yongmoonchun during the study period.

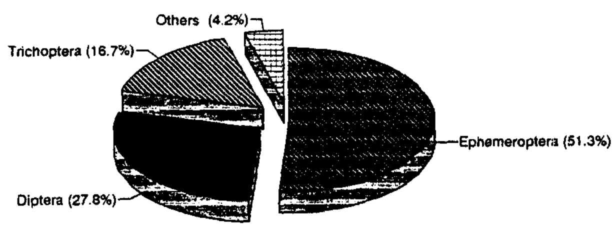

Fig. 4. Abundance (No. /0.5 m^2) of major taxa from the Yongmoonchun.

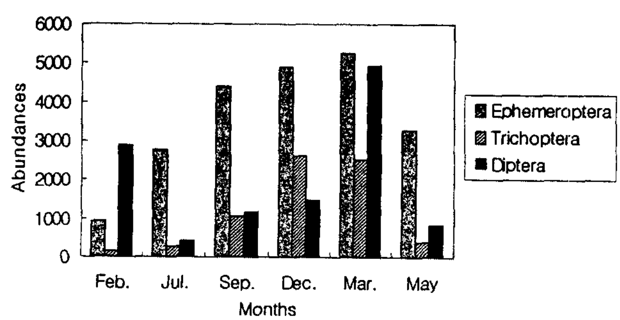

Fig. 5. Abundance(No. /0.5 m^2) of major taxa from the upper stream of Mt. Yongmun during February, 1991-May.1992.

after mid '91 (Fig. 5).

Variation of dominant species

Table 1 shows the seasonal percentage of dominant species shared at each experimental site. In Feb. 1991, Chironomidae become the 1st dominant species at four locations and second dominant species at three locations. While Chironomidae became dominant species at 1 location in Sept. '91 and Mar. '92, Ephemeroptera dominated over others in July, '91 and May, '92 (Table 2). Chironornidae was largely made up with Ortho chadiinae sp. 2 and Ephemeroptera was composed with *E. kibunensis* and *S. rufa* as main species. It indicates that these species have broader endurance ranges against pollutants than others in each family. Particularly, it reaffirms that Ortho chadiinae sp. 2 habitats in the area with little pollution, *E. kibunensis* and *S. rufa* live relatively in less polluted area.

Following sampling sites, Diptera appeared as the dominant species at sites 1 and 2 and Ephemeroptera at sites 3, 4 and 5. Analyzing monthly calculations, Ephemeroptera is the dominant species all year long except in Feb. with Diptera being dominant (Table 3). With those results, it seems that site 1 was more polluted than sites downstream. When examining changes of dominant species, Diptera shows higher

Table 2. Percent abundance of dominant species at each site

Month	Site	Dominant species			
		First D.S	(%)	Second D.S	(%)
'91 Feb.	1(Sinjŏmni)	Ortho chadiinae sp.2	66.6	Tanypodinae sp.2	12.3
	2(Ochonni)	*Ephemerella keijoensis*	17.7	*E. latifolium*	16.1
	3(Chohyŏnni)	*Chironomus* sp.1	21.1	*E. latifolium*	17.9
	4(Chohyonni)	Ortho chadiinae sp.2	69.2	Tanypodinae sp.2	13.1
	5(Dukchonni)	Ortho chadiinae sp.2	34.8	Ortho chadiinae sp.4	7.2
'91 July	1(Sinjŏmni)	*E. latifolium*	29.4	*Baetis nla*	20.2
	2(Ochonni)	*B. nla*	20.9	*E. latifolium*	17.8
	3(Chohyŏnni)	*B. nla*	13.9	*E. latifolium*	12.8
	4(Chohyonni)	*E. latifolium*	29.4	*E. kibunensis*	15.1
	5(Dukchonni)	*E. kibunensis*	37.3	*E. latifolium*	17.9
'91 Sep.	1(Sinjŏmni)	*E. kibunensis*	14.4	*E. latifolium*	19.7
	2(Ochonni)	*Chironomus* sp.1	24.8	*E. kibunensis*	18.1
	3(Chohyŏnni)	*E. kibunensis*	53.1	*Chironomus* sp. 1	10.5
	4(Chohyonni)	*E. kibunensis*	24.3	*Hydropsyche* KUb	16.9
	5(Dukchonni)	*E. kibunensis*	43.6	*C.* sp.1	12.3
'91 Dec.	1(Sinjŏmni)	Ortho chadiinae sp.1	65.4	*R. a. coreana*	11.2
	2(Ochonni)	*Serratella. rufa*	29.7	*C. castanea*	10.3
	3(Chohyŏnni)	*S. rufa*	27.7	*H.* KUe	18.2
	4(Chohyonni)	*S. rufa*	23.6	*H.* KUb	10.5
	5(Dukchonni)	*E. latifolium*	30.3	*E. kibunensis*	18.0
'92 Mar.	1(Sinjŏmni)	Ortho chadiinae sp.2	47.6	*C.* sp.	31.6
	2(Ochonni)	*E. yoshidae*	22.2	*C.* sp.1	21.8
	3(Chohyŏnni)	*S. rufa*	28.2	*C.* sp.1	11.8
	4(Chohyonni)	*S. rufa*	29.5	*H.* KUe	16.7
	5(Dukchonni)	*E. latifolium*	18.5	*E. kibunensis*	18.4
'92 May	1(Sinjŏmni)	*E. kibunensis*	27.9	Ortho chadiinae sp.2	17.8
	2(Ochonni)	*E. kibunensis*	35.3	*B. nla*	11.6
	3(Chohyŏnni)	*E. kibunensis*	26.0	*S. rufa*	19.7
	4(Chohyonni)	*E. kibunensis*	50.6	*B. nla*	16.7
	5(Dukchonni)	*E. kibunensis*	56.4	*C.* sp.1	15.6

Table 3. Dominant benthic macroinvetebrates as situal and annual average level

Site average			Annual average		
Site	Dominant species	Occupying(%)	Dates	Dominant species	Occupying(%)
1	Ortho chadiinae sp. 2	20.3	Feb.	Ortho chadiinae sp. 2	21.2
2	*C.* sp. 1	13.6	Jul.	*E. latifolium*	9.3
3	*S. rufa*	20.3	Sep.	*E. kibunensis*	9.3
4	*S. rufa*	17.7	Dec.	*S. rufa*	7.3
5	*E. kibunensis*	24.2	Mar.	*S. rufa*	7.1
			May	*E. kibunensis*	10.3

occupying percentage than Ka--pyong Chun (Yoon *et al.* 1990) which means that the whole creek is influenced by pollutants. There are no sampling sites where Diptera became a dominant species in July and Dec. This could have resulted from heavy rainfall in the summer and decreasing polluted water volume in Dec. Following seasonal variations of dominant species, there is a greater possibility in '92 to improve the water quality of the creek than in '91.

Variation of biological indexes

In terms of monthly average, the seasonal dominant indexes of each site is highest in Feb. '91 and lowest in Mar. '92. Also, site 5 shows the highest dominant index and site 4 the lowest. When comparing among the sites, Fig. 6 shows the changes of the seasonal dominant indexes at each site. The seasonal dominant index varies with large differences at each sites. The dominace index appears the highest in Mar. at site 5, Feb. at site 4, Sept. at site 3, May at site 2 and Feb. at site 1. Drawing the graph as a whole, sites 1 and 4 have the most variation of diversity index and dominace index. With these results, sites 1 and 4 indicate an overgrowth of specific species due to bad environmental conditions. These also show the same results by means of physicochemical study. The monthly richness index came up from 6.71 to 9.17 and from 8.74 to 10.92 among study sites.

Fig. 7 shows the seasonal richness index at each sites. Sites 1 and 2 have the widest range of index numbers and the others are limited within from 3.63 to 5.91 range. Diversity index at all sites show be-

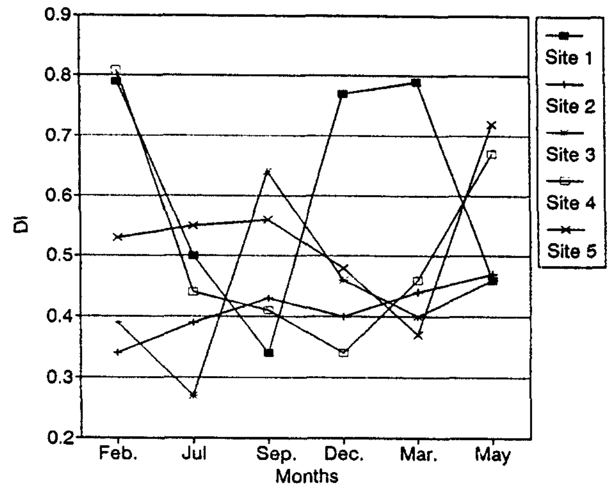

Fig. 6. Seasonal variation of dominant index(DI) at each sites.

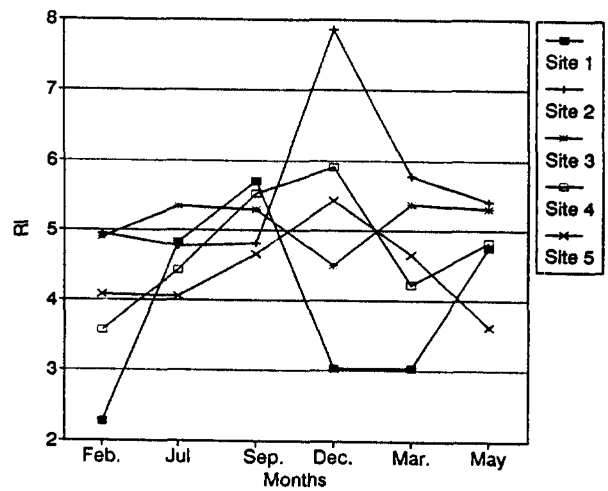

Fig. 7. Seasonal variation of richness index(RI) at each sites.

tween 2.35 and 2.88 by seasonal bases and between 2.77 and 2.92 by experimental sites. The whole picture shows wide range of differences such as 1.23 at site 1 in Feb. '91 and 2.81 at site 3 in July, '91. When analyzing seasonal variations at each experimental site, there are some environmental changes of living conditions during study periods at sites 1 and 4. This is because of large differences of diversity index. Especially, site 1 has the possibility of being influenced by the direct influx of pollutants or environmental changes of living conditions (Fig. 8). One can see the ecological stability of benthic macroinvertebrates in winter or early spring time because of the high diversity index in Dec. and Mar. Evenness index shows from 0.57 to 0.67 by seasonal bases and from 0.63 to 0.70 by monthly bases. Since sites 1 and 4 showed the widest seasonal changes in evenness index as well as diversity index. There seems to be a high correlation between 2 index (Fig. 9).

Human and water pollution

Table 4 shows the number of households, population, restaurants, motel, pastures and live stock which could influence the water quality of Mt. Yong Moon Creek. Since Mt. Yong Moon is a popular resort area, the upper part of the creek shares the

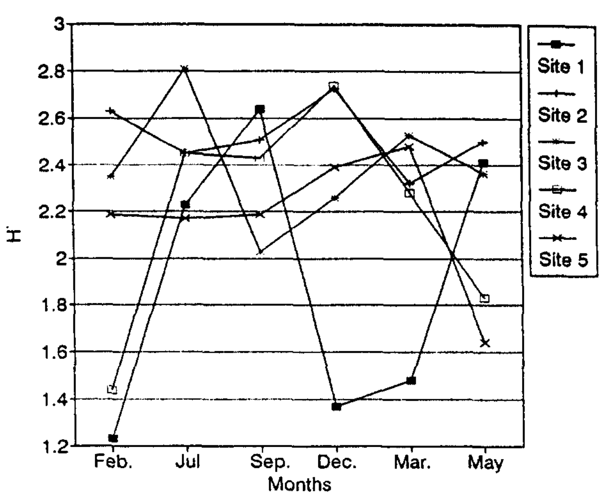

Fig. 8. Seasonal variation of diversity index (H') at each sites.

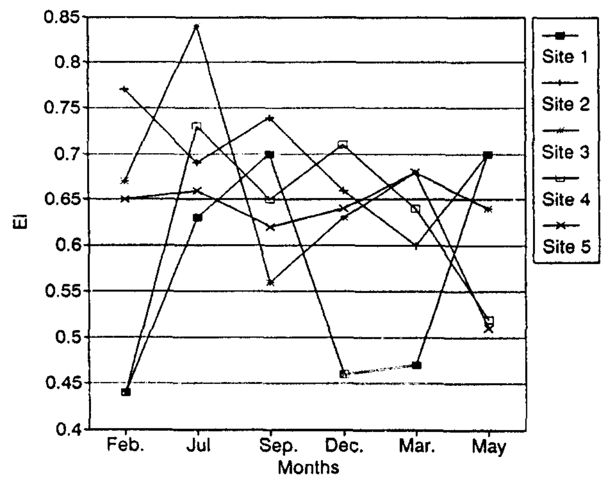

Fig. 9. Seasonal variation of evenness index (EI) at each sites.

most part of households and population and the lower part has the most pastures and live stock. Especially, restaurants, motels and recreational facilities are located densely at the upper part of the creek. In general, the trend is to have a considerable increase of tourists and cars, The most increased amount of tourists were in Oct. and May and the least in Dec.

Comparing tourist number and biological indexes, it takes certain period of time (about a month or less) to get influences of biological indexes after the tourist have increased. When combining the biological indexes with physicochemical factors, it appears to take a lot shorter time to influence biological indexes than biological indexes itself. Particularly, water quality becomes more deteriorated following rising temperature and it indicates acceleration of down turn curve on the graph due to the greatest increase of tourist number in Oct. While DO was a relatively high at most sites in Dec., site 1 had the highest diversity indexes, which is standard in classifying water quality in Dec., site 2 having higher number than site 1 in general. Despite an increase of pollutants in the summer, it has a high diversity indexes. This indicates that pollutants are flushed

Table 4. Source of pollution in the Yongmoonchun

Site	Household	Population	Restaurants	Motel	Pastures	Livestock	
						Hog	Cattle
1	185	621	12	27	3	0	45
2	55	209	4	2	2	0	48
3	23	94	0	0	0	15	3
4	102	350	1	2	4	165	103
5	106	376	1	5	14	75	34

down to the lower part of the creek due to heavy rainfall and that low diversity indexes in the drying season is due to less rainfall. Therefore, it is concluded that site 1 is the most polluted among all study sites.

적 요

용문산 계류의 조사에서 출현한 저서성 대형 무척추동물의 총분류군은 5문 7강 17목 141종으로 나타났다. 총 출현종수의 지점간 변동은 적었다. 계절별로는 지점간 변동보다 큰 변화를 보였다. 이것은 지점별로는 서식 환경 상태가 비슷하나 계절별로는 차이가 보이고 있으므로 외부의 오염원에 영향을 받은 것으로 볼 수 있다.

전 조사 지점의 총 개체수현존량은 41,920개체/0.5m² 이고 평균 개체수현존량은 8,384개체/0.5m² 이며 이 중에서 하루살이류가 우점하는 곤충류는 40,934개체/0.5m²로 나타났다. 지점간 변화는 매우 컸다. *E. kibunensis*가 우점하는 Site 5는 환경 상태가 악조건으로 특정 분류군이 우점하고 있었다. 계절별로는 91년 2월의 우점종인 Ortho chadiinae sp. 2가 차지하는 비율이 21.2%이었다. 지점별로는 점유율이 높았지만 계절별로는 91년 2월을 제외하고는 10%이하로 점유율이 낮았으므로 안정적이었다. 또한 91년 2월 이전과 이후의 변화로 보아 환경 개선의 요인이 있었던 것으로 보인다.

전체적으로 볼 때 총 출현개체수는 추워짐에 따라 증가하는 경향을 보이고 있으며 분류군별로는 플라나리아류가 3월 이후의 생장기에 꾸준한 성장을 보이는 반면 빈모류의 경우는 없었다. 다만 곤충류가 온도가 상승할수록 감소하는 경향을 보이고 있다. 이는 하루살이류, 깔다구류가 주류를 이루는 곤충류가 3월말 이후 우화기에 접어들기 때문인 것으로 보인다. 그러나 타종과의 경쟁력 때문에 감소하지는 않는 것으로 판단된다. 왜냐하면 총개체수에서 비교가 되지 않기 때문이다. 전체 평균 수준에서 제1우점 분류군인 하루살이류가 전체의 51.3%, 제2우점 분류군인 파리류가 27.8%, 제3우점 분류군인 날도래류는 16.7%의 점유율을 보였다.

본 조사에서 생물 지수의 변동으로 살펴볼 때 계절별로는 하절기에, 조사 지점별로는 Site 5와 Site 1이 불안정한 서식 환경을 보였고 오염원이 비교적 적은 Site 3에 비해 유원지나 목장 등의 오염 물질 유입원이 존재하는 Site 1이 더욱 오염되어 있다는 것을 알 수 있었다.

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