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Pre-Monsoon Dynamics of Zooplankton Community in the Downstream of the Gagok Stream, Eastward into the East Sea, Korea

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Abstract - **Pre-monsoon dynamics of zooplankton community were investigated in the downstream of the Gagok stream flowing into the East Sea of Korea. Monthly sampling was carried out to collect zooplankters at five sites in the stream during the period between April and July 2014. Dissolved oxygen contents exceeded 7.0 mg L^{-1} all the time. Water temperature was in a range of 15.7 to 24.9°C and pH 7.4 to 8.8, respectively. A total of 75 taxa consisted of 36 species of rotifers, 16 species of cladocerans, 16 species of copepods, four kinds of aquatic insects, two kinds of decapods and one nematod was occurred. One species of marine copepod and one cladoceran, and one species of brackish rotifer and one copepod distributed at the station located in the stream mouth. Zooplankton abundance showed to vary from 42 to 4202 individuals m^{-3} due to the explosion of aquatic insects and *Alona* sp. at site 2 located in the downstream in April. Heavy rainfall during the monsoon period seems to decrease the zooplankton abundance caused by diffusion and drifting to the sea. Species diversity indices were generally high between 1.2~2.3 and were recorded to be high at the downstream throughout the study period. With the zooplankton dynamics, the influence of the input of sea waters into the stream seemed to be confined to some hundred meters of the stream mouth facing the East Sea.**

Key words: zooplankton community, downstream, sea water input

INTRODUCTION

The Gagok stream is a short stream of 41 km long with high velocity and flows eastward from its source in the Taebaek mountainous area of altitude higher than 1,000 meters and directly into the East Sea (Sea of Japan). This shallow stream had been heavily contaminated with coal mines for several decades and restored recently with the stop of mining activity.

Although fast streams with shallowness are unsuitable environments for zooplankton distribution, this stream provides more or less lentic waters sporadically with several banks for the water supply of paddy fields near the stream and bottle-necked mouth into the sea.

Biological studies on the stream biota of eastward streams into the East Sea are rare (Kim 1970; Cho *et al*. 1975) with a little ones in east costal lagoons (Kim and Kang 2003; Gil *et al*. 2007; Park *et al*. 2014). Zooplankton ecology in mountainous streams flowing eastward into the East Sea should be quite different from those in big rivers flowing into the Yellow Sea and the South Sea (Yoo and Lim 1992; Kim and Lee 1999, 2007; Kim *et al*. 2002; Song *et al*. 2003). In earlier months of the pre-monsoon period, east coastal streams could show similar characteristics in zooplankton dynamics to those in alpine environments with melting waters of snow (cf. Khamisa *et al*. 2014).

Little is known on zooplankton ecology in east coastal streams in Korea. This pathbreaking study on zooplankton

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dynamics might lead to know more about the faunal study of the stream biology in the east coast of Korea.

MATERIALS AND METHODS

1. Study area

The Gagok stream is the short stream of 41 km long, flowing along the border between Gangwon-do and Gyeongsang-buk-do. The stream flows rapidly due to its source locating at the Taebaek mountainous area of altitude higher than 1,000 meters and directly heading to the East Sea. The shallow stream of 2~3 meters depth had been heavily contaminated with coal mines for several decades and restored recently with the stop of mining activity. Moreover the construction of ecological park being planned by the local government along the riverside of the stream might cause the drastic change of stream biota (Alexander and Allan 2007). Although the stream mouth facing the East Sea, sea waters merely affect the stream biota probably because of the high velocity of the stream and the low tidal rage of some ten centimeters in the study area.

Zooplankton sampling was carried out at five sites (Fig. 1).

2. Sampling methods

Quantitative sampling was carried out to collect zooplankters with conical net (mouth diameter 25 cm, mesh aperture 0.05 mm) attached flow-meter (Hydrobios model 438 110) to the net mouth. Oblique hauling was adopted at five sites in the Gagok stream monthly during the pre-monsoon period from April to July 2014. Environmental factors of water temperature (0.1°C accuracy thermometer), pH (TI SenzpH duo) and dissolved oxygen contents (CHEmetrics K-7512) were measured simultaneously with the zooplankton collection, respectively.

3. Sample examinations and data analysis

Collected samples were fixed with 4% neutralized formaldehyde in a 300 mL bottle. Crustacean specimens were identified with stereomicroscope (Zeiss SV11 Mag. X165) and with compound-microscope (Zeiss Auxiolab Mag. X400), respectively (cf. Chihara and Murano 1997; Mizuno

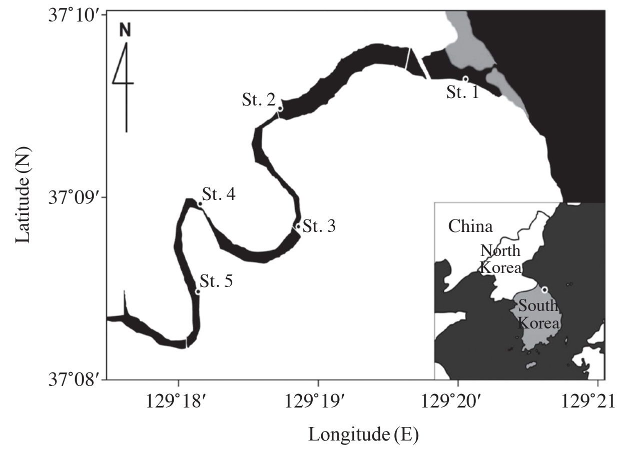

Fig. 1. Map showing the sampling site to investigate zooplankton dynamics in the Gagok stream flowing eastward into the East Sea, Korea.

and Takahashi 1999; Seo 2010; Yoon 2010; Chang 2010, 2012; Jeong 2013).

At least the 1/10 of sample was examined to estimate the abundance of each taxa of zooplankton by using of the data obtained from flow-meter readings and the relationship between environmental parameters was observed.

Photos of typical zooplankton species occurred in the stream were taken with photomicrography and shown in the appendix (LEICA ICC50HD, OPTICAM KCS-3.1C).

Species diversity indices (Shannon and Weaver 1963) were calculated with the data of the abundance of each taxon using a Primer 5 (Plymouth Routines in Multivariate Ecological Research).

RESULTS

A total of 75 taxa consisted of 36 species of rotifers, 16 species of cladocerans, 16 species of copepods, four kinds of aquatic insects, two kinds of decapods and one nematod was occurred (Table 1). One species of marine copepod and one cladoceran, and one species of brackish rotifer and one copepod distributed at site 1 being located in the stream mouth facing the sea.

Spatio-temporal variations in the number of species occurred showed that the maximum number of 15 species was recorded at sites 2 and 5 in April, and the minimum of six species at site 4 in July, respectively (Fig. 2). Sites 2 and 5

Table 1. List of zooplankton species occurred in the Gagok stream in pre-monsoon period between April～July 2014

	Species		Species
Rotifera		Cladocera	
(brackish)	*Brachionus plicatilis*	(marine)	*Evadne nordmanni*
(fresh)	*Ascomorpha ovalis*	(fresh)	*Alona affinis*
	Brachionus budapestinensis		*Alona costata*
	Brachionus calyciflorus		*Alona guttata*
	Brachionus forficula f. angularis		*Alona karua*
	Brachionus urceolaris		*Alona rectangula*
	Brachionus sp.		*Alona* sp.
	Euchlanis dilatata		*Alonella excisa*
	Lecane aculeata		*Bosmina longirostris*
	Lecane curvicornis		*Chydorus gibbus*
	Lecane hastata		*Chydorus ovalis*
	Lecane inermis		*Chydorus sphaericus*
	Lecane luna		*Chydorus* sp.
	Lecane subtilis		*Graptoleberis testudinaria*
	Lecane tudicola		*Leydigia propinqua*
	Lecane ungulata		*Pleuroxus* sp.
	Lecane sp.		
	Lepadella latusinus var. *americana*	Copepoda	
	Lepadella oblonga	(marine)	*Microsetella norvegica*
	Lepadella quadricarinata	(brackish)	*Thermocyclops taihokuensis*
	Lepadella sp.	(fresh)	*Canthocamptus mirabilis*
	Monostyla closterocerca		*Canthocamptus* sp.
	Monostyla crenata		*Cyclops strenuus*
	Monostyla hamata		*Diacyclops disjunctus*
	Monostyla lunaris		*Eucyclops serrulatus*
	Monostyla unguitata		*Eucyclops* sp.
	Monostyla sp.		*Macrocyclops albidus*
	Notholca striata		*Maraenobiotus brucei*
	Notommata crytopus		Copepoda nauplius
	Pompholyx complanata		Copepodite
	Pompholyx sulcata		Unidentified Calanoida sp.
	Proales cryptopus		Unidentified Cyclopoida sp.
	Scaridium longicaudum		Unidentified Harpacticoida sp. 1
	Trichocerca cylindrica		Unidentified Harpacticoida sp. 2
	Trichocerca marina		Unidentified Harpacticoida sp. 3
	Trichotria polcilum		
Decapoda		Insecta	
	Decapoda larvae		Aquatic insect larvae 1
	Decapoda sp.		Aquatic insect larvae 2
			Aquatic insect larvae 3
Nematoda			Aquatic insect larvae 4
	Nematoda sp.		

were revealed to have the prosperity in the number of species occurred during the pre-monsoon period in the Gagok stream.

Zooplankton abundance showed to vary from 42 to 4,202 individuals m^{-3} due to the explosion of aquatic insects and *Alona* spp. at site 2 in April (Fig. 3). Except this explosion and high abundances around 1,000 individuals m^{-3} at site 1 in June and July, zooplankton abundances were always recorded some hundreds individuals m^{-3} in the Gagok stream.

Species diversity indices were ranged between 1.2～2.3 and generally high with values higher than 2.1 at site 2 during the study period (Fig. 4).

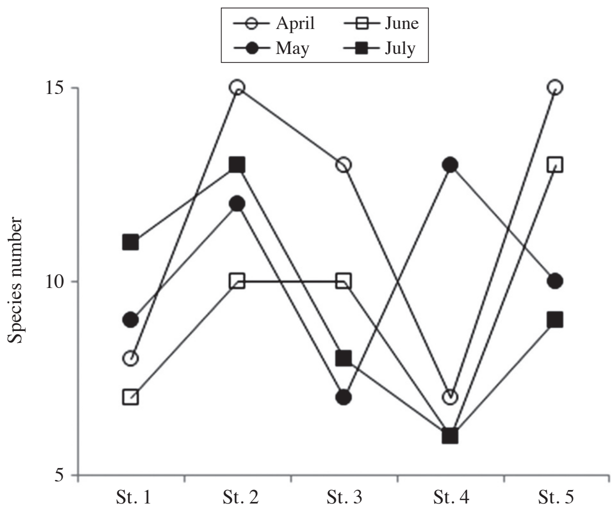

Fig. 2. The number of species occurred in the Gagok stream in the pre-monsoon period between April~July 2014.

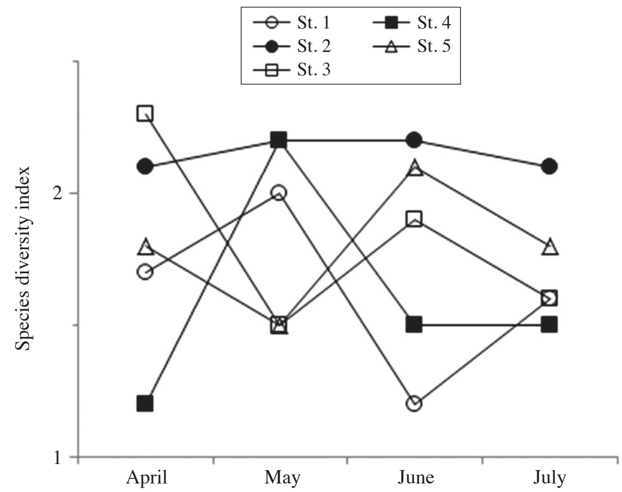

Fig. 4. Species diversity index in the Gagok stream in the pre-monsoon period between April~July 2014.

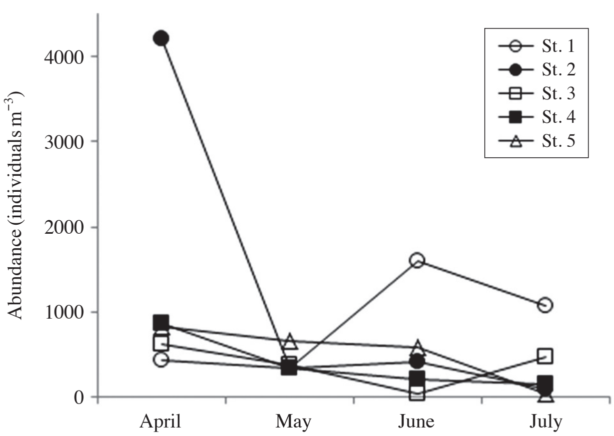

Fig. 3. Zooplankton abundance in the Gagok stream in the pre-monsoon period between April~July 2014.

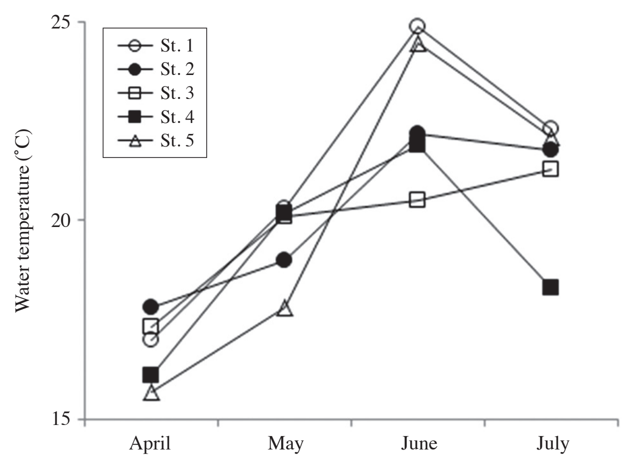

Fig. 5. Water temperature in the Gagok stream in the pre-monsoon period between April~July 2014.

Dissolved oxygen contents varied between 7.0~10.0 mg L^{-1} throughout the study. Water temperature increased gradually from 15.7 to 24.9°C and pH fluctuated between the range 7.4~8.8, respectively (Figs. 5, 6).

DISCUSSION

In general, shallow streams with high velocity provide unfavorable environments for zooplankton distribution due to weak swimmers. Aquatic insect larvae are rather dominant even in plankton fauna (Chung 2008; Marshall and Gladyshev 2009). In the study stream, however, most sites showed somewhat lentic characteristics except site 3. Because site 1 is located just inside of the stream mouth which has been narrowed and blocked with sand dune (Fig. 1). Other sites are located at the upper side of the bank which has been constructed for the storage of agricultural water to the rice paddy.

In temperate monsoon region, water temperature increases gradually during the period from spring until the beginning of monsoon. Decrease of water temperature in July when compared with that in June was the momentary case due to the rain fall just before the field investigation in July.

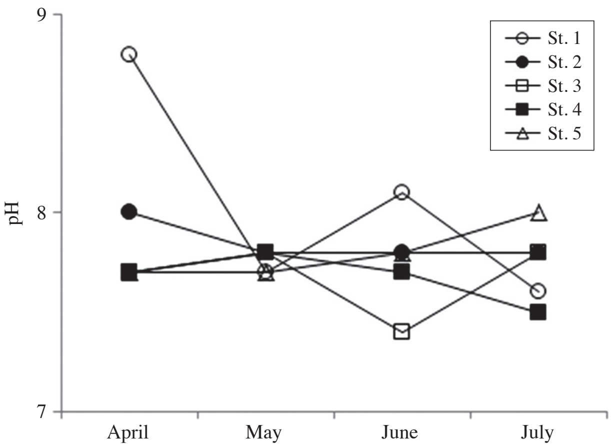

Fig. 6. pH in the Gagok stream in the pre-monsoon period between April∼July 2014.

pH data also support this result. Site 1 showed high pH value throughout the study except July. This means that sea water affects the site 1 environment at all time. When rain falls, the dissolution of limestone in upstream raises pH of upper waters then drops gradually downward with neutralization. It is clear that dissolved oxygen contents is not a limiting factor for zooplankton distribution in the study stream because of exceeding seven mg L^{-1} all the time.

The occurrence of two species of marine zooplankton, *Evadne nordmanni* and *Microsetella norvegica*, is the evidence of the input of seawater into site 1. *E. nordmanni* is recorded to be the typical pre-monsoon species or spring species (Yoo and Kim 1987; Kim 1989) and *M. norvegica*, all the year round in coastal waters of Korea, respectively. The influence of seawater input, however, seems to be confined to site 1 and the brackish zone is very narrow because that the occurrence of brackish zooplankters is poor with only two species of *Brachionus plicatilis* and *Thermocyclops taihokuensis*. Stream mouth of bottle necked shape could prevent the vigorous inflow of seawater.

Drastic decrease of zooplankton abundance is due to the depletion of stream waters as a result of water supply to rice fields in June. No such a decrease was observed at site 1 because salty water is useless for the agriculture. Moreover this decrease, heavy rainfall might decrease the zooplankton abundance once again with the diffusion and drifting to the sea during the monsoon period.

With this study, seawater could not affect the zooplankton fauna at sites 2∼5, then the formation of brackish zone seems to be confined to site 1. Species diversity index was highest at site 2. This prosperity suggests that the downstream provides more favourable habitats for zooplankton distribution than those in upper stream (cf. An and Shin 2005).

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REFERENCES

Alexander GG and JD Allan. 2007. Ecological success in stream restoration: case studies from the midwestern United States. Environ. Manage. 40:245-255.

An K-G and I-C Shin. 2005. Influence of the Asian monsoon on seasonal fluctuations of water quality in a mountainous stream. Korean J. Limnol. 38:54-62 (in Korean).

Chang CY. 2010. Invertebrate Fauna of Korea, Continental Harpacticoida, 21(4). National Institute of Biological Resources, Ministry of Environment. 244pp.

Chang CY. 2012. Invertebrate Fauna of Korea, Continental Cyclopoida I, 21(19). National Institute of Biological Resources, Ministry of Environment. 92pp.

Chihara M and M Murano. 1997. An illustrated guide to marine plankton Japan. Tokai University Press, Simizu (in Japanese).

Cho KS, SU Hong and KH Ra. 1975. The comparative study of limnological conditions and plankton fauna of brakish water in the east coast of Korea. Korean J. Limnol. Soc. 8:25-37 (in Korean).

Chung K. 2008. Body length-mass relationships of aquatic insect of mountain streams in Central Korean peninsula. Korean J. Limnol. Soc. 41:320-330 (in Korean).

Gil J-W, Y-P Hong and S Kim. 2007. Fish fauna in southern river of Bukcheong and brakish lakes, Shinpo district, North Korea. Korean J. Environ. Biol. 25:279-287 (in Korean).

Jeong HG. 2013. Diversity of freshwater Cladocera (Crustacea: Branchiopoda) in the south of Korean Peninsula. PhD Dissertation, Hanyang University, Seoul.

Khamisa K, DM Hannah, LE Brown, R Tiberti and AM Milnera. 2014. The use of invertebrates as indicators of environmental change in alpine rivers and lakes. Sci. Total Environ. 493:1242-1254.

Kim H-W and HY Lee. 2007. The differences of zooplankton dynamics in river ecosystems with and without estuary dam in river mouth. Korean J. Limnol. Soc. 40:273-284 (in Korean).

Kim JW. 1970. Standing crops of the aquatic insects communities in the east-coastal river in Korea. Korean J. Limnol. Soc. 3:15-22 (in Korean).

Kim S. 1989. Studies on the ecology of marine cladocerans in the northwestern Pacific Ocean. PhD Dissertation, Hiroshima University, Hiroshima.

Kim S and JH Lee. 1999. Environmental studies of the lower part of Han River IV. Zooplankton dynamics. Korean J. Limnol. Soc. 32:16-23.

Kim S, M-S Han, K-I Yoo, K Lee and Y-K Choi. 2002. Zooplankton and phytoplankton dynamics with the construction of river mouth dam in Kum River estuary, Korea. Korean J. Limnol. Soc. 35:141-144.

Kim S and Y-S Kang. 2003. Brackish lakes in Shinpo district, North Korea. I. Zooplankton. Korean J. Limnol. Soc. 36: 215-220.

Marshall HG and MI Gladyshev. 2009. Neuston in aquatic ecosystems. pp. 97-102. In Encyclopedia inland water (Likens G ed.). Academic press, Cambridge.

Mizuno T and E Takahashi. 1999. An illustrated guide to freshwater zooplankton in Japan. Tokai University Press, Simizu (in Japanese).

Park S, Y Jang, K Lee, W Heo, K Cho and H Choi. 2013. Analysis of fish community of lagoons in the East seashore accoring to hydrach succession. Korean J. Limno. Soc. 47: 83-99 (in Korean).

Shannon CE and W Weaver. 1963. The mathematical theory of communication. University of Illinois Press, Urbana.

Soh HY. 2010. Invertebrate Fauna of Korea, Marine planktonic copepods, 21(3). National Institute of Biological Resources, Ministry of Environment. 197pp.

Song YH, WC Lee and I-S Kwak. 2003. Study on response-species zooplankton to the seasonal changes precipitation and temperature. Korean J. Limnol. Soc. 36:9-20 (in Korean).

Yoo K-I and Kim S-W. 1987. Seasonal distribution of marine cladoceans in Chinhae Bay, Korea. J. Oceanol. Soc. Korea 22:80-86.

Yoo K-I and Lim B-J. 1992. Seasonal succession in the abundance and community structure of zooplankton in Pal'tang reservoir. Korean J. Limnol. Soc. 25:89-97.

Yoon SM. 2010. Invertebrate Fauna of Korea, Branchiopods, 21(2). National Institute of Biological Resources, Ministry of Environment. 156pp.

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APPENDIX.

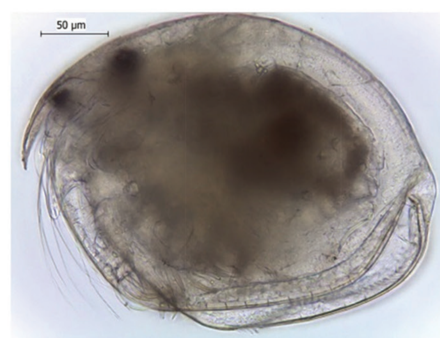
Evadne nordmanni
St. 1 in May

Brachionus budapestinensis
St. 1 in June

Lecane pertica
St. 1 in July

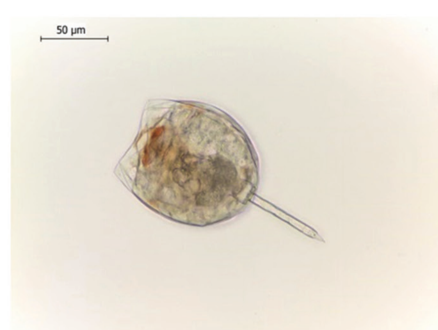
Alona costata
St. 2 in April

Graptoleberis testudinaria
St. 3 in July



Chydorus ovalis
St. 4 in July

Lecane curvicornis
St. 4 in June



Monostyla lunaris
St. 5 in July