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Note

Spatial Dynamics of Diatom Community in the Mid to Lower Part of the Nakdong River, South Korea

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Phytoplankton community dynamics were studied from 2004 to 2006 with two and four weeks interval at mid to lower part of the Nakdong River (Waegwan: RK 194, Goryeong: RK 157, Jukpo: RK 112, Namji: RK 75 and Hanam: RK 63: RK: distance from the Estuarine Barrage), South Korea. Annual averages of water temperature was about 16°C, and dissolved oxygen was ranged between 10.0 and 11.5 mg L^{-1} (percent saturation, 106.5 to 112.8%). Diatoms were dominant group with over 60% of phytoplankton abundance in all study sites (Waegwan: 64%, Goryeong: 69%, Jukpo: 73%, Namji: 79%, and Hanam: 83%). However, the occasional dominances of other groups such as green algae and blue-green algae were observed from March to October. *Stephanodiscus hantzschii* was dominant species and the relative abundances were high at all study sites (48-72%). The ratio of *S. hantzschii*/total phytoplankton abundance were showed a clear increasing tendency toward the estuarine barrage: i.e. 0.31 at Waegwan, 0.39: Goryeong, 0.50: Jukpo, 0.56: Namji, 0.60: Hanam. The results of this study provide the information that the phytoplankton community structure in a regulated river system is basically affected by the physical properties such as water velocity and retention time, resulting in single species dominance by the stagnancy of river flow.

Key words : *Stephanodiscus hantzschii*, water velocity, diatom, phytoplankton, Nakdong River

Various factors affect ecological dynamics in river systems. Bauder (2005) suggested that the total amount of seasonal precipitation is the most important factor affecting river ecosystem dynamics. In most cases, the patterns of flow in a large river channel are recognized as a primary factor, because river ecosystems are usually characterized by flow regulation (Stober and Nakatani, 1992). Channelization or hydroelectric dams regulate mostly large rivers in Europe, North America and East Asia (Thornton *et al.*, 1990). These physical alterations have the potential to induce cultural eutrophication, as well as dramatic change in the hydrology and ecology of large river system (Ha *et al.*, 2003). Consequently, many scientists suggested the importance of flow regulation in lotic environment in terms of ecological characteristics (Maheshwari *et al.*, 1995; Rader and Belish, 1999; Bertrand *et al.*, 2001; Joo and Jeong, 2005). In a river, the flow regulation probably one of the most important factors associated with phytoplankton dynamics and water quality (Kim *et al.*, 2005).

The Nakdong River flows southeastward of the Korean peninsula. The Nakdong River is the longest river in South Korea, with a main channel that is 526 km in length and a total drainage area of 23,817 km^2. This river is located between

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35°N-37°N and 127°E-129°E. The Nakdong River is a major source of drinking water for the residents of the catchment area, which are approximately over 10 million people. There is a clear seasonality of rainfall and discharge in the river basin. Summer (June to early September) rainfall occupies over 50% of the total annual rainfall, while there is scant rainfall during the winter (ca. 10%, December-February; Ha *et al.*, 2002). The rainfall during summer (June to September) provides over 50% of the annual total, while precipitation is scant during the winter. In order to manage the water resources owing to the high demand for water resources, five multipurpose dams were constructed in the upper part of the river and major tributaries, and an estuarine dam was constructed in 1987 to prevent salt water intrusion into the drinking water intake facility. These anthropogenic physical alterations and human influences have caused changes in hydrological dynamics and accelerated the eutrophication of the river (Ha *et al.*, 1998; Park *et al.*, 2002). These anthropogenic alterations and human influences have caused changes in hydrological dynamics and accelerated the eutrophication of the river (Ha *et al.*, 1998; Park *et al.*, 2002), resulting in serious diatom blooms (*S. hantzschii*) in the river system. In this study, a brief relationship between the *S. hantzschii* dominance in the phytoplankton community and the hydrological characteristics of the mid to lower Nakdong River was explored by field survey.

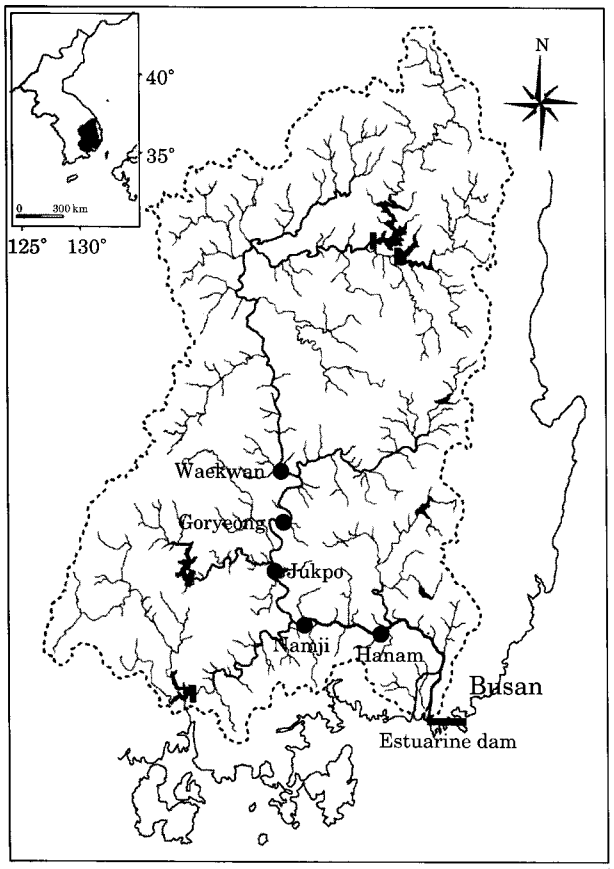

Fig. 1. The Nakdong River basin and study sites (Waezkwan, Goryeong, Jukpo, Namji, Hanam).

This study was conducted from 2004 to 2006 at mid to lower part of the Nakdong River (Waegwan: RK 194, Goryeong: RK 157, Jukpo: RK 112, Namji: RK 75 and Hanam: RK 63: RK: distance from the Estuarine Barrage), South Korea (Fig. 1). Once two or four weeks, the water samples were collected at each study site, and the following water quality parameters were measured: water temperature, pH, and concentrations of dissolved oxygen (DO), silica (SiO_2). Water temperature and DO were determined with a YSI DO meter (model 58) and an Orion pH meter (model 250A) was used to measure pH. Water samples were filtered using Whatman GF/C filters (model 1822 047) to determine the silica concentrations and these filtrates were analyzed by a QuikChem Automated Ion Analyzer. The phytoplankton samples were immediately preserved with Lugol's solution. Phytoplankton was

Table 1. Investigated parameters: silica, water temperature, dissolved oxygen and pH (2004-2006) (n=46-61).

	Waegwan RK* 194	Goryeong RK 157	Jukpo RK 112	Namji RK 75	Hanam RK 63
Silca (mg L^{-1})	7.1±2.8	7.0±3.5	6.7±3.5	6.1±3.2	6.7±3.4
Water temp. (°C)	16.2±8.8	16.2±8.6	16.1±8.8	15.9±8.8	15.5±8.8
DO (mg L^{-1})	11.4±2.6	10.8±2.6	11.5±3.2	11.0±3.0	11.4±3.4
DO (%)	112.8±17.6	106.5±15.1	111.5±19.4	106.9±16.4	108.8±17.8
pH	7.8±0.9	7.8±0.8	7.9±0.9	7.9±0.9	8.8±0.9

*: distance from the estuarine barrage (km)

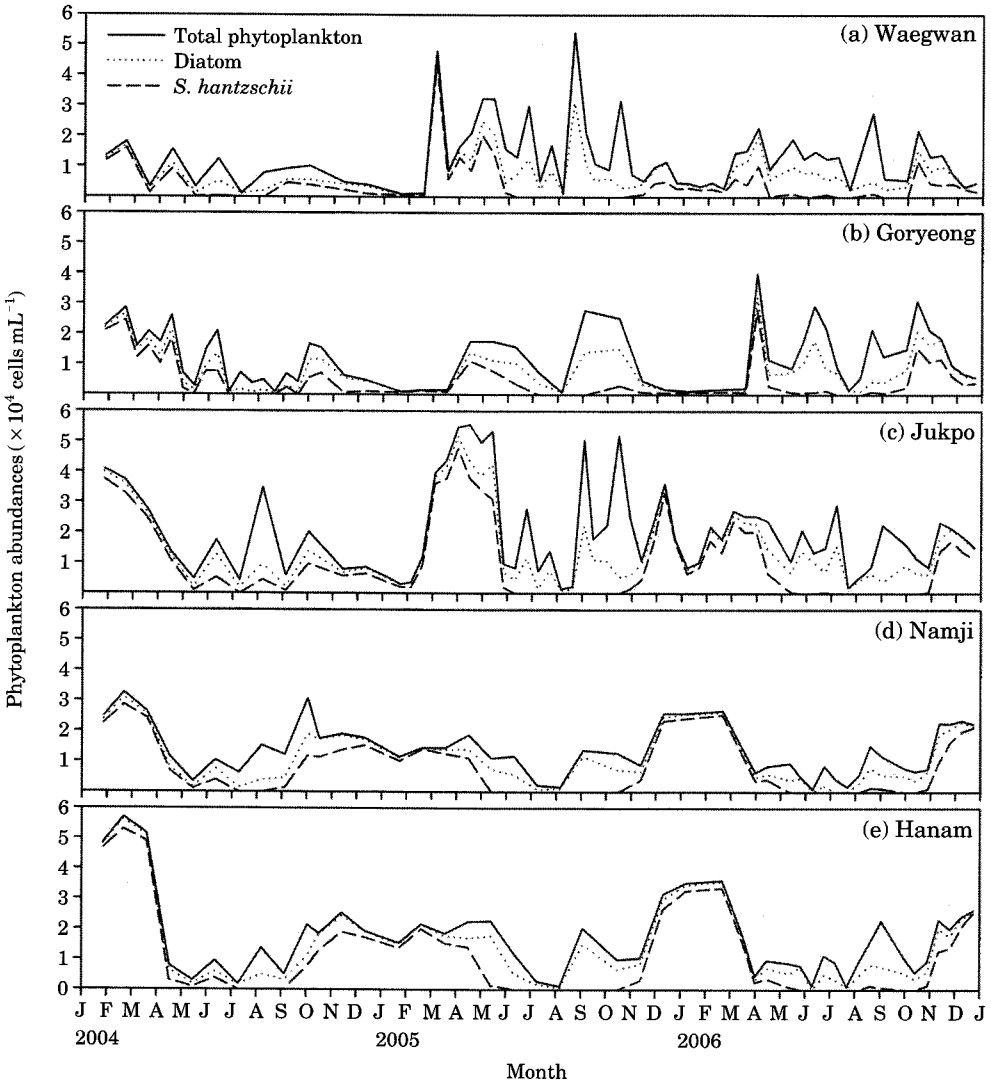

Fig. 2. Changes of phytoplankton abundances in the Nakdong River.

enumerated using an inverted microscope (ZEISS Telaval 31) by the Utermöhl's sedimentation method (Utermöhl, 1958). Identification of phytoplankton species was conducted with a light microscope (ZEISS Axiolab) and based on the following keys: Foged (1978), Cassie (1989), Round *et al.* (1990) and Cox (1996). Water velocity at each sampling station was calculated using the value of discharge and flow section area, provided by the Ministry of Construction & Transportation.

Annual average of water temperatures was about 16°C and the average of mid part was slightly higher than lower part among the study sites. This is because the samples were collected from the lower to the mid part during the survey. The average value of silica concentration at Waegwan was slightly higher than other study sites. Dissolved oxygen concentration averages were 10.0 to 11.5 mg L^{-1} and the degree of saturations were 106.5 to 112.8%. In pH variation along the spatial locations, those value in the mid parts (Namji to Waegwan) were slightly lower than in the lower part of the river (Hanam).

There was a remarkable spatial and temporal dynamics of phytoplankton community in the Nakdong River. Diatom was dominant in every study site and over 60% of total phytoplankton abundance in the Nakdong River. Diatom abundance tended to increase toward lower part of the

Table 2. Water velocity, diatom/phytoplankton ratio, *S. hantzschii*/diatom ratio and *S. hantzschii*/phytoplankton ratio.

	Waegwan RK 194	Goryeong RK 157	Jukpo RK 112	Namji RK 75	Hanam RK 63
Water velocity (m s^{-1})*	0.44±0.22	0.36±0.29	0.40±0.39	0.33±0.31	0.31±0.26
Diatom/total phytoplankton ratio	0.64	0.69	0.73	0.79	0.83
S. hantzschii/diatom ratio	0.48	0.57	0.68	0.71	0.72
S. hantzschii/total phytoplankton ratio	0.31	0.39	0.50	0.56	0.60

*: We calculated the value using the variation of discharge and flow section area of Ministry of Construction & Transportation.

river (Waegwan: 64%, Goryeong: 69%, Jukpo: 73%, Namji: 79%, Hanam: 83%) (Table 2). Occasional dominance of other groups was observed between March and October (2004-2006) (Fig. 2). The high dominance of diatom was observed from every winter to early spring (from November to April) when low temperature was persisted, and this circumstance was clear in the lower sites (Namji and Hanam) (Fig. 2).

During the diatom-dominating period, *S. hantzschii* was the main diatom taxon and the relative abundances of the species were quite high in every study site. Both ratio of *S. hantzschii*/total phytoplankton abundance and *S. hantzschii*/diatom abundance had an increasing tendency toward the lower part of the river (Table 2). For this result, the *S. hantzschii* had higher abundance in lower part of the Nakdong River than mid part of the river. Ha *et al.* (1998) reported that the *S. hantzschii* in the Mulgum (lower longitude than Hanam study site) was over 90% of total phytoplankton while the species was dominated.

There was significant negative relationship between water velocity and *S. hantzschii*/phytoplankton ratio (Table 2). The determination coefficient (r^2) was −0.68 (n=5, $p<0.05$). Lee and Han (2004) suggested that the phytoplankton community structure have a quite different succession pattern in eutrophic water system with different retention time. Vollenweider (1982) demonstrated the importance of retention time in aquatic system as a major control on the ability of planktonic algae to utilize nutrients. John *et al.* (2006) suggested that planktonic algal biomass increased along the length of a river however, in the upper reaches of the river at least, the biomass of planktonic algae in the water column never proliferated. Also, this is because the initial biomass of algae at the start of the growing period at the upper reaches of the river is always small due to the high rate of flushing rate. Water velocity is related to retention time, and hence increased retention time reflects a favorable circumstance for *S. hantzschii* development at the lower part of the river. It is thought that the construction of estuarine barrage has its impact up to Hanam and Namji.

We suppose the winter diatom, *S. hantzschii*, may be influenced by complex interactions between biotic- and abiotic environmental factors, and proliferated in the Nakdong River every year. However, the abundance was different along longitudinal location because of the water velocity, and the retention time may basically affect the growth of the diatom species.

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