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# Seasonal Fluctuation of Chlorophyll *a* Concentration in the Size Fractionation of Phytoplankton in Daechung Reservoir

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**Since a substantial part of the total planktonic primary production is due to the activity of the picoplankton, seasonal change of chlorophyll *a* in the picoplankton, nanoplankton and microplankton was determined at four locations in Daechung Reservoir from September in 1998 to September in 1999. Chlorophyll *a* concentration (< 200 μm) was 0.7 ~ 36.9 μg/*l* in TAE (Taejeon site), 0.5 ~ 23.5 μg/*l* in MAN (Man site), 1.9 ~ 20.1 μg/*l* in HOE (Hoenam site), and 0.5 ~ 17.4 μg/*l* in DAM (Dam site). Generally it was observed the the highest concentration of chlorophyll *a* was in September and the lowest in April to June. The relative contribution of chlorophyll *a* of each fraction was changed dramatically through the year. Relative contribution of chlorophyll *a* of microplankton was high from June to October, and low in March in all locations except HOE. However chlorophlyll *a* concentration of picoplankton fraction was 2.0 ~ 24.3% of total chlorophyll *a* (< 200 μm) through the year and did not show any dramatic changes at all locations.**

**Key words : Daechung Reservoir, Chlorophyll *a* concentration, microplankton, nanoplankton, picoplankton**

## INTRODUCTION

Phytoplankton can be categorized as microplankton (20 ~ 200 μm), nanoplankton (2 ~ 20 μm) and picoplankton (0.2 ~ 2 μm) (Pick and Caron, 1987). The contribution of picoplankton to primary production and phototorphic biomass increases in oligotrophic environments, where it can be as much as 90% of total primary production (Li *et al*., 1983; Stockner and Antia, 1986). Because of their smaller size, picoplankton have long been unrecognized in limological studies on phytoplankton.

From the studies of large lakes in the temperate zone (Nagata, 1986, 1990; Weisse, 1988; Fahrenstiel *et al*., 1991), it has been suggested that contributions of picoplankton to total primary production are high, particulary in summer, and consumption of picoplankton by protozoan grazers is important in trophic transfer and nutrient cycling. Munawar and Fahnenstiel (1982) reported that 37 ~ 50% of chlorophyll *a* and 28 ~ 55% of $^{14}$C-bicarbonate uptake were attributed to the phytoplankton of the < 3 μm fraction in Lake Superior. Craig (1984) also reported that 24 ~ 97% of the photoassimilation of $^{14}$C-bicarbonate was found in the < 3 μm fraction in a Canadian oligotrophic lake. Thus, it is assumed that the microbial loop operates actively in large lakes. The soluble organic carbon has been produced by several planktonic processes, and a part of particulate organic carbon that is not edible for zooplankton operate into the grazing food chain cycling through the microbial loop. However, it is difficult to determine the

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amounts of carbon transfer through the loop.

For the basic study of microbial food web in Daechung Reservoir, we evaluated the size distribution of phytoplankton on the basis of chlorophyll *a* concentration in the Reservoir during September in 1998～September in 1999 and tried to find the main environmental factor of phytoplankton fractional abundance.

## MATERIALS AND METHODS

### Sampling locations

The sampling was carried out between September in 1998 and September in 1999 at four locations in Daechung Reservoir (Fig. 1). Since the water is stagnant in the vicinity of Taejon Intake Tower (TAE site), algal bloom was common every summer. Estuary (MAN site) is located in the middle distance between Dam and TAE. The water from upstream is mixed with the stagnant water near dam. Hoenam Bridge (HOE site) is located in the upper part of the Reservoir and water quality parameters have strongly been influenced by the precipitation. It was reported that algal growth potential in the semdiment porewater was high (Shin and Cho, 2001) and algal bloom was common in summer at this location. Dam site (DAM) is the deepest and is located in lower part of the main stream.

### Water quality parameters

10 L of water was sampled once to four times a month from September in 1998 to September in 1999. The temperature, pH and DO of the water was measured by multiprobe (YSI 6000) on site. Samples for measuring water quality parameters (DO, SS, $NH_3$−N, TN, TP) was taken separately and carried in the ice box to the laboratory and stored in the refrigerator before analysis. Water samples for nutrient measurements were filtered through 47 mm Whatman GF/C glass fiber filters. All the water quality parameters was analyzed according to APHA−AWWA−WPCF (1989). For SS (suspended solids) measurement, water samples was filtered through GF/C filter and dried in 105°C for 2 hours and calculated the differences of the weight of the filter. $NH_3$−N was measured by phenate method. TN and TP was analyzed by UV specrophotmetric method and ascorbic method respectively after persulfate digestion.

**Fig. 1.** The sampling sites in Daechung Reservoir. TAE, Taejon Intake tower: MAN, Estuary: HOE, Hoenam Bridge: DAM, Daechung Dam.

### Measurement of chlorophyll *a* fractions

Whole water sample (0.5～2 L) was filtered through various meshes (3, 20, 200 μm) separately in the dark and the filtrate was refiltered through GF/C filter. The GF/C filters was homogenized with 90% acetone in the chilled mortar and pestle and stored in the refrigerator for 24 hours. The opaque samples were centrifuged at 500 g for 20 minutes and the absorbance of the upper part was measured at 630 nm, 647 nm, 664 nm, 750 nm with spectrophotometer (Shimazu UV−2401PC). From those values, chlorophyll *a* concentration in picoplankton (0.2～2 μm), nanoplankton (2～20 μm) and microplankton (20～200 μm) were calculated. For this study, picoplankton were defined as organisms $<3$ μm in all dimensions. This size is slightly larger than the 2 μm definition used by Pick and Caron (1987) but similar to the size used by Stockner and Antia (1986). Either definition could be used with similar results (Sicko−Goad and Stoermer, 1984; Nagata, 1986; Fahnenstiel and Carrick, 1992).

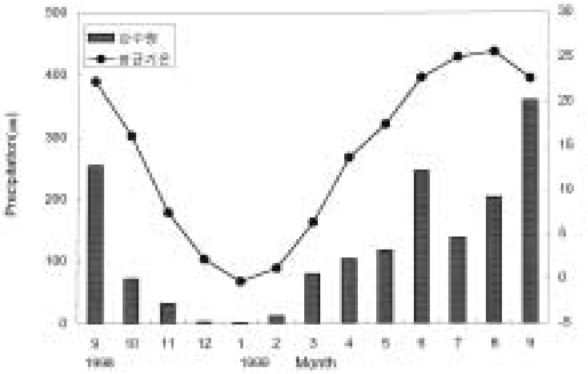

**Fig. 2.** Monthly variation of temperature and precipitation in Taejon.

## RESULTS AND DISCUSSION

### Climate

It was reported the annual rainfall was 1,137 mm since Daechung Reservoir was constructed and 85% of rainfall was concentrated in the rainy season (June−September). The annual rainfall was 1,246 mm and air temperature was −0.3∼25.6°C during the experiment period (Fig. 2). The temperature and rainfall data were obtained from Taejon Meteorological station.

### Seasonal abundance of Chlorophyll *a* concentration ($<$200 μm)

Chlorophyll *a* concentration ($<$200 μm) increased in July to October and decreased in winter and spring at all locations. In TAE site, the chlorophyll *a* concentration was 27.4∼36.9 μg/*l* in September to October, decreased to 5 μg/*l* in April and began to increase in May (Fig. 3). The highest concentration of chlorophyll *a* was 36.9 μg/*l* in September at TAE site. In MAN site, Chlorophyll *a* concentration was 22.2∼23.5 μg/*l* in September and October and began to decrease at the end of October (Fig. 4). In HOE site, Chlorophyll *a* concentration was 13.9∼20.1 μg/*l* in September and October and increased in June (Fig. 5). In DAM site, chlorophyll *a* was 8.4∼17.4 μg/*l* in September and October and lower than those in three other sites (Fig. 6). Generally, there were two peaks of chlorophyll *a* in Daechung reservoir. One peak was observed in September to October due to the increase of blue−green algae. The other one was in January due to the increase of *Stephanodiscus* (Shin *et al*., 1999). Two peaks were observed in all locations. Chlorophyll *a* concentration ($<$200 μm) at all locations were almost the same as those of total chlorophyll *a* concentration in the previous reports (Oh, 1998; Shin and Cho, 1999).

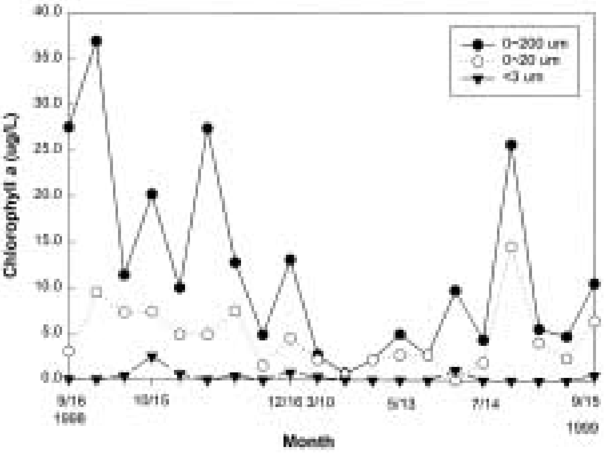

**Fig. 3.** Monthly variation of chlorophyll *a* concentration by size classes at TAE site.

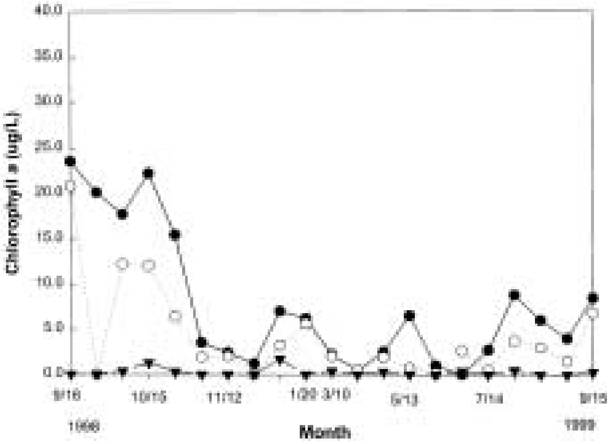

**Fig. 4.** Monthly variation of chlorophyll *a* concentration by size classes at MAN site. The symbols are same as in Fig. 3.

### Seasonal changing pattern of the chlorophyll *a* concentration of each size fraction

Chlorophyll *a* concentration of picoplankton (0.2∼2 μm), nanoplankton (2∼20 μm) and microplankton (20∼200 μm) was calculated. Chlorophyll *a* concentration of microplankton was 0.1∼27.4 μg/*l* in TAE, 0.2∼20.1 μg/*l* in MAN, 0.1∼

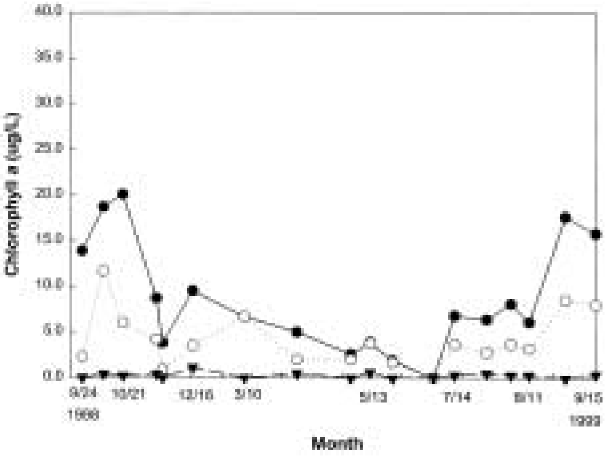

**Fig. 5.** Monthly variation of chlorophyll *a* concentration by size classes at HOE site. The symbols the same as in Fig. 3.

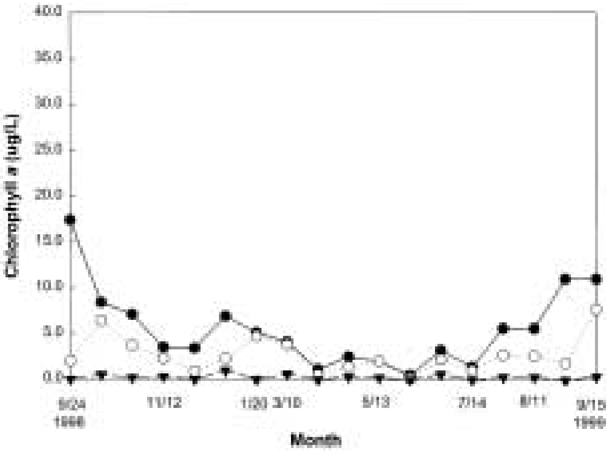

**Fig. 6.** Monthly variation of chlorophyll *a* concentration by size classes at DAM site. The symbols the same as in Fig .3.

14.1 μg/*l* in HOE and 0.3 ~ 15.4 μg/*l* in DAM. The lowest value was observed in March to April and the highest value in September to October. Chlorophyll *a* concentration of nanoplankton is 0.1 ~ 15.7 μg/*l* at all locations in September in 1998 ~ September in 1999. Nanoplankton was 0.1 ~ 13.4 μg/*l* in TAE, 0.1 ~ 13.9 μg/*l* in MAN, 0.1 ~ 1.5 μg/*l* in HOE and 0.1 ~ 3.0 μg/*l* in DAM. The changing pattern of the chlorophyll *a* concentration of nanoplankton was almost similar to that of microplankton, but the degree of change was not drastic. The changing pattern of the picoplankton chlorophyll *a* was quite different from that of the larger fractions. The chlorophyll *a* concentration of picoplankton was 0.1 ~ 2.5 μg/*l* and small fraction of chlorophyll *a* in picoplankton was observed. Picoplankton was 0.3 ~ 2.5 μg/*l* in TAE, 0.3 ~ 1.7 μg/*l* in MAN, 0.1 ~ 1.1 μg/*l* in HOE and 0.2 ~ 1.0 μg/*l* in DAM. It is noteworthy that no significant change in the chlorophyll *a* concentration of picoplankton was found. Nagata (1986) reported the same results observed in Lake Biwa. The chlorophyll *a* concentration of picoplankton was 0.4 ~ 0.7 μg/*l* in June to July, a peak (0.9 μg/*l*) in August and maintained a level of 0.3 ~ 0.4 μg/*l* in Lake Biwa, Japan. Microscopic examination demonstrated that the major biomass of the picoplankton was attributable to chroococcoid cyanobacteria in Lake Biwa (Nagata, 1986). In marine systems this population consists largely of chroococcoid cyanobactearia and minute eukaryotic algae (Johnson and Sieburth, 1979; Waterbury *et al.*, 1979; Johnson and Sieburth, 1982).

For this study, we measured only chlorophyll *a* concentration of phytoplankton fraction, but epifluorescence microscopic techniques were used for the study of nanoplankton and picoplankton because it enabled the accurate determination of bacterial densities in the picoplankton size class (0.2 ~ 2 μm) (Hobbie *et al.*, 1977; Watson *et al.*, 1977; Caron *et al.*, 1985). These estimates are much greater than estimates from traditional procedures (Jannasch and Jones, 1959).

Fahnenstiel and Carrick (1992) measured the density and seasonal pattern of occurrence of picoplankton in Lakes Huron and Michigan and found that the picoplankton abundance in surface waters is from 10,000 to 20,000 cells/mL and similar to values reported for freshwater and shelf marine environments (Nagata, 1986; Weisse, 1988). In temperature aquatic environments, maximum seasonal picoplankton abundance occurs during thermal stratification (Caron *et al.*, 1985).

## The relative contribution of the chlorophyll *a* of each size fraction

Fig. 7 shows the seasonal changes occurring in the size composition of chlorophyll *a*. Seasonally, a clear changes in the size structure of chlorophyll *a* was found. From June to October the major proportion (82.2%) of chlorophyll *a* was

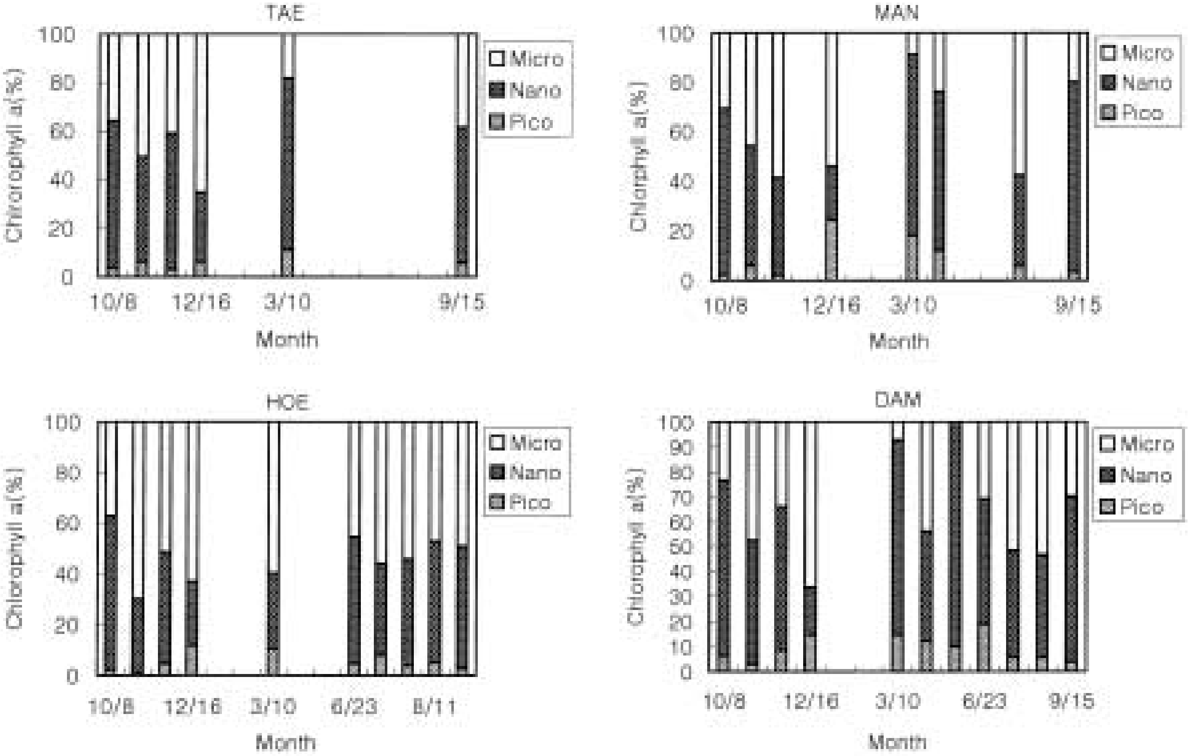

**Fig. 7.** Percent of chlorophyll *a* concentration by size classes at TAE, MAN, HOE and DAM site.

found in the nano− and microplankton fraction while only 1.0～18.8% of the chlorophyll *a* (<200 µm) was found in the picoplankton fraction. From November to May in the next year, the relative contribution of the >20 µm was decreased to a minimum of 40%, while that of the picoplankton chlorophyll *a* were relatively constant, ranging from 6.0～24.3%. The contribution of the chlorophyll *a* concentration of nanoplankton were higher and relatively constant, ranging from 18.8～76.4%. Similar results was reported by Nagata (1986). We did not observed the vertical changes in this study, Nagata (1986) reported that no clear vertical trend in the distribution and composition of the <3 µm chlorophyll *a* to the total chlorophyll *a* was found.

Phytoplankton that passed through 3− and 1−µm screens were responsible for 48 and 20% of the primary production respectively in Lake Superior (Fahnenstiel *et al.*, 1986). Their importance appeared to be a consistent feature of Lake Superior, since little seasonal or yearly variability was found. The exact role of these small cyanobacteria in the Lake Superior food web is uncertain; inevitably some portion of this production must be consumed directly. In many marine systems, protozoans are an important link in the food web as part of the so−called "microbial loop" (Azam *et al.*, 1983). Heterotrophic protozoans provide the link between small producers and larger multi−cellular zooplankton (Linsley *et al.*, 1983). Picoplankton−protozoan trophic coupling is important in the pelagic food web and biogeochemical cycling of Lake Baikal during summer (Nagata *et al.*, 1994)

## Correlation with water quality parameters

pH, DO, $NH_3$−N, TN, TP and SS (Suspended solids) was measured and calculated the correlation coefficient of chlorophyll *a* concentration and water quality parameter to find out which factor is the main factor related with chlorophyll *a* fraction (Table 1). All data from all locations were collected and the correlation coefficient between chlorophyll *a* concentration of each size fraction and environmental factor was calculated. Microplankton and nanoplankton has a negative correlation with DO (Fig. 8). Correlation coefficient of chlorophyll *a* concentration with DO

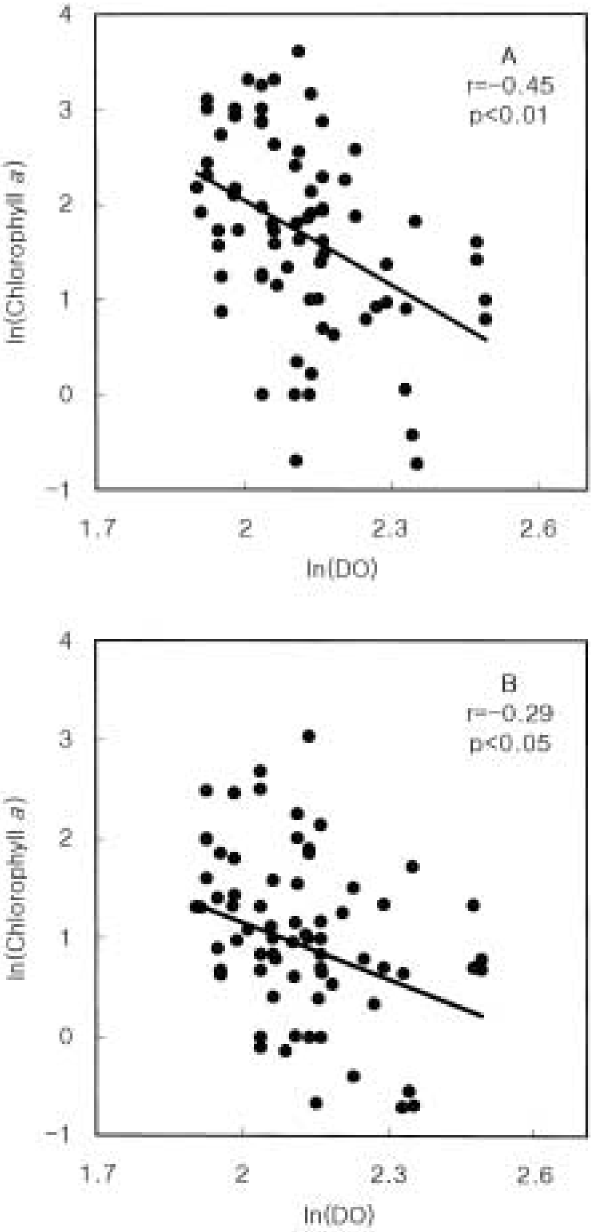

**Fig. 8.** Relationship between DO (Dissolved Oxygen) and chlorophyll *a* concentration (A: microplankton, B: nanoplankton).

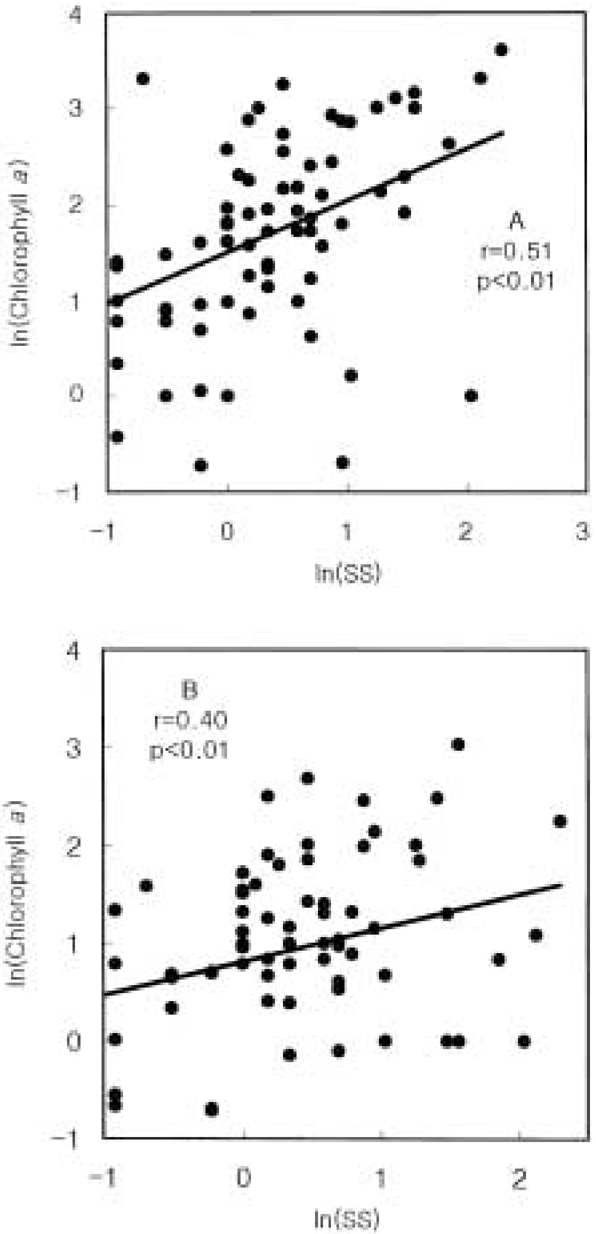

**Fig. 9.** Relationship between SS (Suspended solids) and chlorophyll *a* concentration (A: microplankton, B: nanoplankton)

is $-0.45$ ($p<0.01$) in microplankton and $-0.29$ ($p<0.05$) in nanoplankton. However correlation coefficient of chlorophyll *a* fraction with SS is 0.51 ($p<0.01$) in micorplankton and 0.40 ($p<0.01$) in nanoplankton (Fig. 9). We do not know how SS influences the abundance of microplankton and nanoplankton.

Generally, DO was low and SS was high in eutrophic lakes. It seemed that high chlorophyll *a* concentration of larger phyoplankton might have some effect to decrease of DO and increase of SS.

In this work, a quite different pattern of seasonal change in chlorophyll *a* of the picoplankton from those of larger phytoplankton was demonstrated in the Daechung Reservoir. The contri-

**Table 1.** Correlation coefficients calculated with Chlorophyll *a* concentration and Environmental parameters.

| | Microplankton | Nanoplankton |
|---|---|---|
| Water temp. | 0.27 | 0.05 |
| pH | 0.10 | −0.27 |
| DO | −0.45** | −0.29* |
| $NH_3$−N | −0.12 | −0.17 |
| T−N | −0.28** | −0.25* |
| T−P | −0.10 | 0.43 |
| SS | 0.51** | 0.40** |

*: Significant
**: Highly significant

bution of the picoplankton chlorophyll *a* increased from 1.0 to 18.8% of the chlorophyll *a* ($<200$ μm). The drastic change in the size structure of the phytoplankton community seemed to involve some interesting problems associated with the physiological and morphological properties (nutrient uptake, sinking loss, and grazing pressure) of the phytoplankton of each size fraction, which deserved further study. Moreover, further research will be needed to clarify the contribution of picoplankton to the primary production of Daechung Reservoir, and the trophic linkages between picoplankton and the feeders which ingest picoplankton.

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**<국문적요>**

# 대청호에서 식물플랑크톤 크기에 따른 엽록소 농도의 계절적 변화

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여러 지역의 호소환경에서 picoplankton이 중요한 일차 생산자로 보고되고 있는데 대청호에서 이를 조사하기 위하여 1998년 9월부터 1999년 9월까지 식물플랑크톤 크기에 따른 엽록소 농도의 계절적 변화를 조사하였다. 200 μm 이하의 식물플랑크톤은 대전취수탑에서 0.7~36.9 μg/*l*, 만입부에서 0.5~23.5 μg/*l* 회남대교에서 1.9~20.1 μg/*l*, 대청댐에서 0.5~17.4 μg/*l*이었는데, 조사지점 4곳에서 모두 9월에 최대치를 나타내었으며 그 이후는 서서히 감소되어 4~6월에 최소값을 보이는 경향을 나타내었다. 계절에 따른 엽록소 농도의 크기별 조성비율을 보면, 연중 microplankton과 nanoplankton 조성비율은 큰 변이를 보였는데, 회남 대교를 제외한 조사지역 3 곳에서 6~10월에는 microplankton의 비율이 높았으나 3월에는 조성비율이 매우 낮은 경향을 보였다. 그러나 조사지역 4곳 모두에서 picoplankton은 연중 2.0~24.3%로 거의 일정하였다.