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Eutrophication and the primary productivity of phytoplankton in Lake Soyang, Korea.

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INTRODUCTION

Determining the trophic state in lakes is essential for the purpose of evaluating and managing the water quality. Generally, nutrients concentration(total phosphorus; TP or total nitrogen; TN), chlorophyll a concentration and transparency have been provided as useful factors to decide the trophic level. A number of researchers have indicated the trophic state using above mentioned parameters[Dillon and Rigler, 1974; Carlson, 1977; Vollenwieder, 1976; Forsberg and Riding, 1980; Aizaki *et al.* 1981]. However, TP and transparency is variable when inorganic particulate materials flow into lake water from watershed. Chlorophyll a concentration was used an indicator for phytoplankton biomass, but it can not be express the production of organic matter by phytoplankton. The ranges in photosynthetic rate have been suggested for determining the trophic state[Rodhe, 1969; Likens, 1975]. However, Ryther[1960] showed that integrate photosynthetic rate over the photic zone in an oligotrophic lake are nearly as high as that in a eutrophic lake. Ichimura and Aruga[1964] have suggested criteria for trophic state with photosynthetic carbon assimilation number(AN, maximal productivity at optimal light intensity in terms of unit amounts of chlorophyll a) which has been known as high values in the high nutrient conditions[Falkowski, 1980].

Lake Soyang constructed in 1973 is located at the upstream part of the Han River in the sparsely populated mountainous district. The shape classified as a long and narrow dendritic reservoir with the length of 60km, and the mean width of 0.5km. The mean hydraulic residence time is about 9 months[Kim, 1987]. The maximum depth is about 100 m at the Dam site. The trophic state of Lake Soyang was assessed as oligotrophy before 1983, mesotrophy from 1984 to 1988, and eutrophy since 1989[Kim *et al.*, 1989].

In the present study, TP, transparency, chlorophyll a concentration, primary productivity of phytoplankton and assimilation number were measured for 8 years from 1986 to 1993. The variations of these parameters is discussed with reference to the eutrophication of Lake Soyang.

METHODS

Water sample was collected monthly at 0, 2, 5m depth at the Dam site. Chlorophyll a concentration was measured by the spectrophotometric method of Lorenzen[1967]. Secchi disc transparency was measured at the shadow side of boat by the white plate of 30 cm diameter. TP was determined by persulfate digestion and ascorbic acid method[APHA, 1989]. The annual loading of TP from watershed was calculated flow rate and TP of major inflow stream at Injae.

Primary productivity of phytoplankton was measured monthly by C-14 uptake with the method slightly modified of vollenweider[1969]. The photosynthetic rates were fitted to a three-parameters P-I model[Platt *et al.*, 1980] by the least square method. Maximal productivity at optimum light intensity(Pmax in $mgC/m^3/hr$), assimilation number or activity coefficient of chlorophyll(AN = Pmax/chl in gC/gChl/hr) and daily primary production integrate over euphotic depth was calculated by the method of Kim and Kim[1989].

RESULTS AND DISCUSSION

Total phosphorus concentration increased from about 8 μg/l in 1987 to about 13 μg/l in 1989, and not showed increasing trend from 1990 just only including high peak in warm season(Fig. 1). Transparency decreased from 1986 to 1989, but annual average values were not changed obviously from 1990(Fig. 2). Since 1990, total phosphorus and transparency were showed considerable variation with season. Increasing trend of chlorophyll a concentration from 1986 to 1990 was shown clearly at the rate of 0.4 μg/l/yr. The advent and expansion of *Anabaena* spp. bloom is thought to be the major cause of chlorophyll a increase and transparency reduction[Kim *et al.*, 1989]. Trophic state of Lake Soyang was described as mesotrophy until 1988, and eutrophy since 1989 according to the total phosphorus concentration, secchi depth and chlorophyll a concentration.

The daily primary production was 0.6-1.0 gC/m^2/day in mesotrophic state until 1989, and 1.0-5.0 gC/m^2/day through warm season, become eutrophic condition after the 1992(Fig. 4).

The monthly variation of assimilation number showed increasing trend with eutrophication(Fig. 5). It could be led increased loading of phosphorus in 1990 which had been limiting nutrient in Lake Soyang. Chlorophyll did not show an increasing aspect under the eutrophic state after the bloom of Anabaena in 1990. That is, the increase of photosynthetic efficiency of phytoplankton. Assimilation number was known as limited by nutrient condition[Falkowski, 1980]. Table 1 shows the primary production and phosphorus input from the watershed and the fishfarms. Organic matter production in Lake Soyang seems to be related with phosphorus input from watershed and fishfarm in lake. Chlorophyll a concentration did not showed an increasing trend since 1990, while the assimilation number of chlorophyll a was higher than mesotrophic period possibly due to the increased nutrients supply. The assimilation number was 2-5 gC/gChl/hr during mesotrophic period and 5-15 gC/gChl/hr during the eutrophic period. Regular pattern of high assimilation number in winter is not observed any more. Assimilation number was over the threshold level of eutrophy by Ichimura and Aruga[1964]. Yearly average of all parameters, which measured in this study, were presented in Table 2. Primary productivity shows general trend of increase from year to year, implying the advance of eutrophication. Assimilation number is thought to be a good parameter defining the trophic state of Lake Soyang.

Table 1. The phosphorus loading and primary productivity of phytoplankton in Lake Soyang.

Year	Phosphorus loading (tP/yr)	Primary production (tC/yr)
1986		3467
1987		12043
1988		7355
1989	82	12024
1990	332	20310
1991	96	9476
1992	152	20034
1993	247	19282

Table 2. Yearly average of secchi disc depth, total phosphorus, chlorophyll a, daily primary productivity and assimilation number in surface of Lake Soyang.

Year	SD m	TP μg/l	Chl. a μg/l	Daily production mgC/m^2/d	AN gC/gChl/hr
1986	4.4		2.2	216	1.8
1987	3.6	8.8	4.4	257	3.0
1988	3.9	12.4	3.4	400	3.3
1989	3.6	12.3	6.1	599	3.9
1990	2.9	13.4	10.0	978	5.5
1991	4.0	11.3	3.1	554	5.7
1992	4.5	12.6	3.9	1251	5.0
1993	4.2	13.2	6.3	1090	6.1

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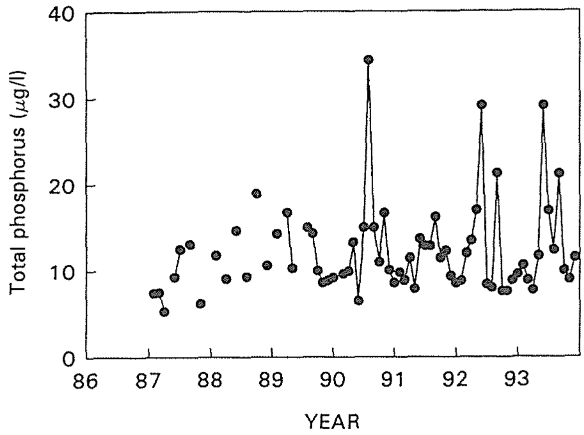

Fig. 1. The monthly variation of total phosphorus at the dam site(averaged surface 5m).

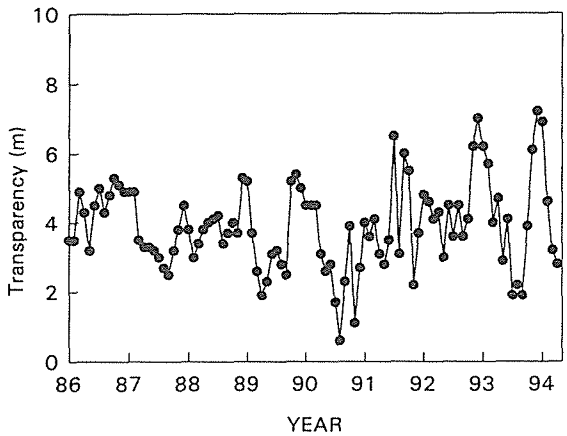

Fig. 2. The monthly variation of secchi disc transparency at the dam site.

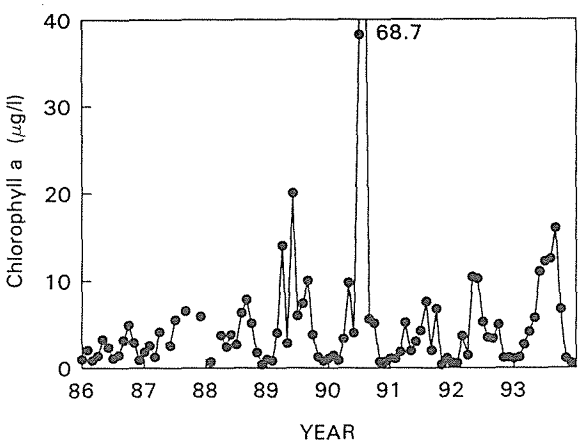

Fig. 3. The monthly variation of Chlorophyll a in Lake Soyang(Averaged surface 5m).

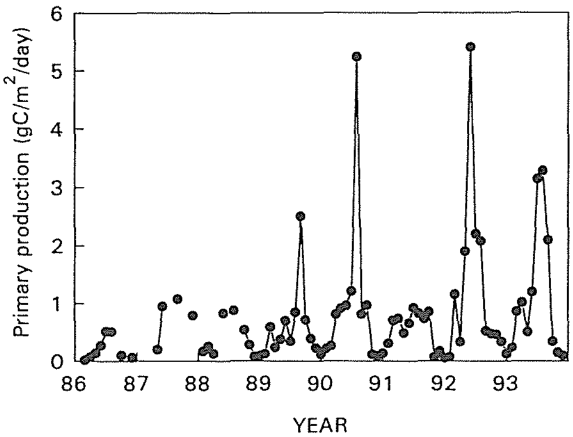

Fig. 4. The monthly variation of primary production at the Dam site of Lake Soyang.

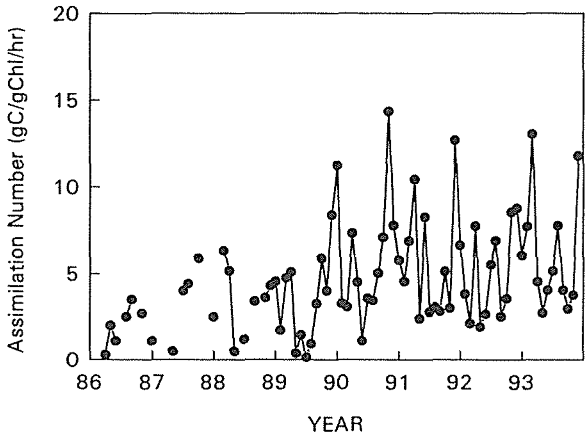

Fig. 5. The monthly variation of assimilation number in surface layer of Lake Soyang.