Korean J. Ecology 7(2) : 61~66, 1984

Seasonal Changes of Environmental Factors and Primary Productivity in the Jido Pond Ecosystem

Lyu, Seung-Won and Seung-Dal Song
(*Dept. of Biology, College of Natural Sciences, Kyungpook National University*)

지도못 生態系에 있어서의 1次 生産性과 環境要因의 계절적 變化

柳 勝 元·宋 承 達
(慶北大學校 自然科學大學 生物學科)

ABSTRACT

Seasonal changes of aquatic environmental factors, phytoplankton biomass and primary productivity were investigated in the Jido pond (a phytoplankton proliferating pond) from August 1982 to October 1983. Secchi disc transparency, pH, alkalinity and inorganic nitrogen concentration ranged 24~105cm, 7.5~10.6, 50~175mg^{CaCO_3}/l 0.1~4.0mg^{N}/l, respectively. The minimum values of transparency, alkalinity and inorganic nitrogen concentration and the maximum value of pH were obtained during the phytoplankton proliferating season. The phytoplankton biomass changed in the range of 51~1146mg^{chl}/m^3 with considerable fluctuations but maintained fairly constant in winter. The maximum and minimum rates of monthly carbon inflow (net primary production) of the phytoplankton community attained 1190g^{C}/m^2 in August 1982 and 68g^{C}/m^2 in February 1983, respectively. The annual rates of inflow and outflow from August 1982 to July 1983 were 7.384 and 7.396kg^{C}/m^2, respectively. Turnover rate of phytoplankton carbon and efficiency of radiation utilization of the phytoplankton community varied in the ranges of 60~130%/day (annual mean, 90%/day) and 0.9~11.2% (annual mean, 6.3%), respectively.

INTRODUCTION

The metabolism of phytoplankton community has been the main subject to aquatic ecosystem researchers, and much effort was made to elucidate the variations of photosynthesis in time and space, and to determine the quantitative primary productivity (Ryther 1956, Talling 1965, Golterman 1971, Jones 1977, Hickman 1979). However, this area still remains as a subject to study further for generalization because of the fast and variable characteristics of phytoplankton community in time and space.

In a sense phytoplankton community is a pool of energy and organic matter. The determinations of the seasonal change of the pool size, of the rate of inflow (net production) and outflow (loss) in natural state are important works to understand the functions of aquatic ecosystem.

In this study, a highly eutrophic pond in which phytoplanktons proliferate was selected as a kind of natural microcosm of a large eutrophic lake, and investigated seasonal changes of phytoplankton biomass and productivity, turnover rate and main environmental factors.

GENERAL DESCRIPTION OF THE STUDY SITE

The Jido pond is located in the center of the Kyungpook National University campus in Daegu at 128°56′ E and 35°33′ N. The pond has a surface area of 993.6m^2 and an average depth of 0.85m with variation range of 0.68～1.08m. The pond is surrounded with a low hill vegetated by pine and willow trees, and a few college buildings located around there, however the northern end has a low land with an overflowing outlet system during the rainy season. The water supply system was established, but was not operated during the study period. Water inputs are considered to be seepage and precipitation. The almost constant water level except rainy days indicates that the seepage inflow is well equilibrated with the seepage outflow and evaporation. There were neither any edge vegetation nor floating hydrophytes, but the dark green color developed owing to the proliferation of phytoplankton. The bottom is flat and composed of bed rocks and mud, however about a half of the bottom area is covered with the sludge (mean thickness, 10cm) presumably composed of phytoplanktonic detritus and mud, which has been sedimented since the pond was constructed in 1978.

Total nitrogen, organic carbon concentration and pH of the bottom sludge was 0.5～0.8g/*l*, 3～5g/*l* and 7～8, respectively, during summer and autumn.

The phytoplankton community was dominated by *Golenkinia* sp. and *Euglena* sp. during summer and autumn in 1982; then *Cyclotella* sp. during winter, *Cyclotella* sp. *Selenastrum* sp. and *Nitzschia* sp. during spring, *Sphaerocystis* sp. *Golenkinia* sp. and *Cyclotella* sp. during summer, and *Cyclotella* sp. during autumn in 1983.

METHODS

Samplings on two weeks interval were made from August 1982 to October 1983, between 10 a.m. and 2 p.m. on each sampling day. The water samples were taken from 30cm below the surface at a fixed station because the horizontal distribution of phytoplankton biomass appears homogeneous and the biomass according to the daily vertical distribution approaches to its mean value at that depth. Secchi disc transparency was measured directly from the site during the sampling. Immediately after the sampling, pH was measured with the Fisher pH meter, alkalinity was determined by titrating with 0.05 N HCl to pH 4.5, and NH_3, NO_2^- and NO_3^- concentrations were measured by Nesslerization, Gries Romijn and Cd reduction method, respectively (Franson 1981). The water samples of 50m*l* were filtered with 0.45μm membrane filter paper, and then chlorophyll was extracted with dimethyl sulfoxide at 65°C for 3 hours (Burnison 1980, Shoaf 1976) and was calculated by the formulae of Parson and Strickland (Strickland and Parsons 1977). Gross primary production was calculated by the formula presented by Smith R.A. (1980), that is; $\sum P = 0.3 Id \cdot \Phi_{max} \cdot Kc \cdot C \{\exp[-3.33\exp(-E \cdot Z_m)] - 0.0357\}/E$, where $\sum P$ is the depth integrated photosynthetic rate (mg^c/m^2/day), *Id* is the total daily insolation (langley), Φ_{max} is the maxmimum photosynthetic quantum yield (mg/einst), *Kc* is the light absorption coefficient per unit chlorphyll, *C* is the mean phytoplankton chlorophyll (mg/m^3), *E* is the total light extinction coefficient per meter, and Z_m is the mixed layer depth (m). In this formula 0.06 mole of carbon and 0.016m^2/mg were adopted for Φ_{max} and *Kc*, respectively (Banister 1974 b, Smith 1980). *E* was determined by measuring the sample water absorbance at 450nm of light wavelength and calculating as follows; $E = 2.3026$ Ab/*d*, where Ab represents the light absorbance and *d* represents the light path length of the spectrophotometer tube (Brower and Zar 1977). With the phytoplankton samples (dominated by *Scenedesmus* sp.) enriched by culture medium, the consumption of oxygen for 3 hours in dark incubator at each temperature of 5°C interval in the range of 0～30°C and the chlorophyll content of each sample were measured, and then the respiration rates per chlorophyll at the respective temperature were calculated (Fig. 1). The respiration rate by the phytoplankton community in this

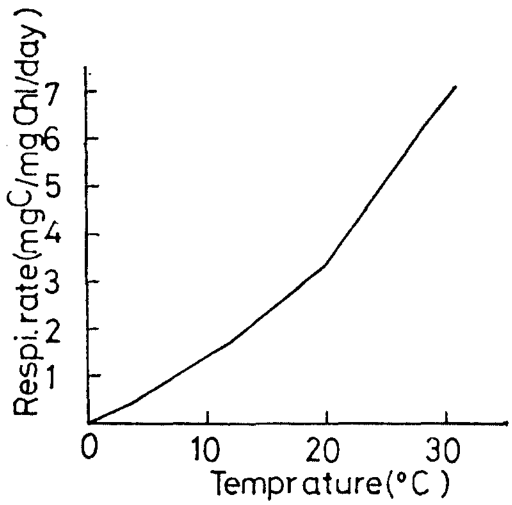

Fig. 1. Relationship between respiration rate per chlorophyll and temperature.

pond ecosystem was determined by multiplying the chlorophyll content of the community by the respiration rate per chlorophyll at the temperature corresponding to the daily mean temperature of the pond. Meteorological data of air temperature (mean, maximum and minimum), cumulative insolation for every 15 days and precipitation for every 10 days procured from the Daegu Meteorological Station located in Daegu city are shown in Fig. 2.

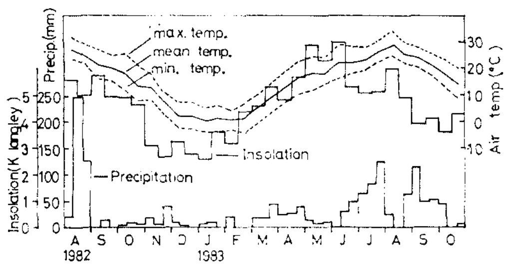

Fig. 2. Seasonal variations of insolation, precipitation and air temperature (max., mean and min.) in Daegu area.

RESULTS AND DISCUSSION

Phytoplankton biomass and environmental factors

Phytoplankton biomass was expressed by chlorophyll amount. Seasonal variation of it showed conspicuous fluctuations with the maximum biomass of 1146 mg^{chl}/m^3 in summer and the minimum biomass of 51 mg^{chl}/m^3 in winter (Fig. 3). Large

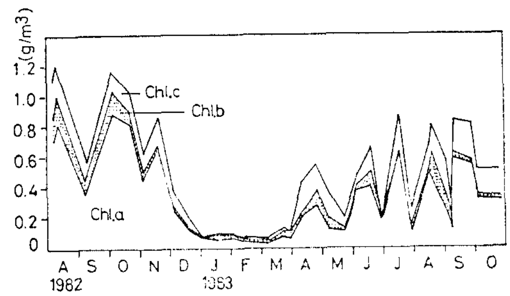

Fig. 3. Seasonal changes of chlorophyll (*a*, *b* and *c*) amounts in the Jido pond ecosystem.

fluctutation occurred during phytoplankton proliferating season may be due to the washout by precipitation because of the smallness and shallow depth of the pond system. On the other hand, Jewson et al. (1981) reported that in a large eutrophic lake ($383km^2$), over 90% of the diatom biomass was lost due to sedimentation, 4% due to grazing, 4% due to parasitism, and only 0.25~0.5% due to washout. The general spring or autumn bloom due to the overturn of water body was not observed in this shallow pond.

The variations of Secchi disc transparency and light extinction coefficient reflected well the phytoplankton biomass fluctuations, and changed in the range of 24~105cm and 9~34, respectively (Fig. 4). The changes of pH ranged between 7.5 and 10.6 showing high values during phytoplankton proliferating season, and that of alkalinity ranged between 50~175mg^{CaCO_3}/l showing high values in winter (Fig. 4). The pH values of this pond during the phytoplankton proliferation are considerably high as natural aquatic ecosystem and indicate the depletion of free CO_2

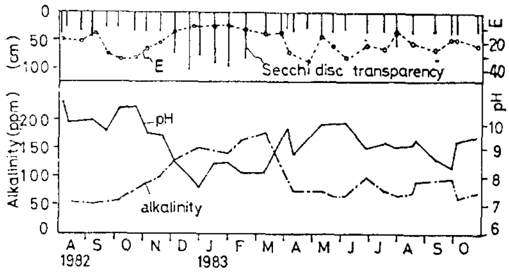

Fig. 4. Seasonal changes of light extinction coefficient per meter(E), Secchi disc transparency, pH and alkalinity in the Jido pond ecosystem.

presumably as a result of intensive photosynthesis.

On the other hand, the low values of alkalinity during phytoplankton proliferating season is considered to be related to the low levels of HCO_3^- owing to the utilization by the phytoplankton photosynthesis. The total dissolved inorganic nitrogen concentration showed wide range of variation, between 0.1 and 4.0mg^N/l, with high values from late autumn to early spring (Fig. 5). The NO_3-N concentration varied in the range of 0.01~1.95mg^N/l with

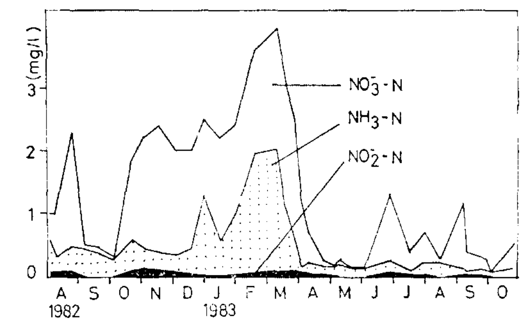

Fig. 5. Seasonal changes of inorganic nitrogen concentrations in the Jido pond ecosytem.

considerable fluctuations, but maintained relatively high values from autumn to spring, the NH_3-N varied in the range of 0.1~2.0mg^N/l showing high values in winter through early spring. The NO_2^--N attained the maximum values of 0.14mg^N/l in late October 1982, showed no seasonal change pattern. The low concentration of inorganic nitrogen during phytoplankton proliferation and the high concentration during winter season indicate that the most of the inorganic nitrogen flowed into and recycled in the nitrogen pool of phytoplankton biomass during proli ferating season and flowed out again during winter.

Phytoplankton production and turnover

The seasonal changes of gross production, respiration rate and efficiency of radiation utilization by the phytoplankton community in this pond ecosystem are shown in Fig. 6. Gross primary production was

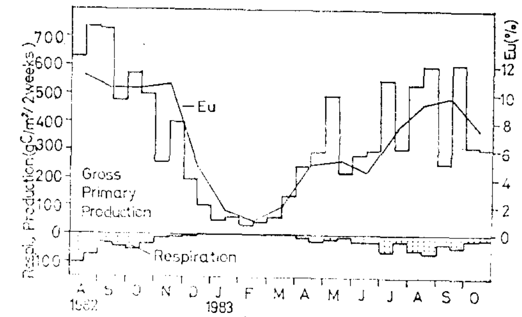

Fig. 6. Seasonal changes of gross production, respiration and efficiency of radiation utilization (Eu) of phytoplankton community in the Jido pond ecosystem.

calculated by the formula of Smith (1980) from the data of chlorophyll, extinction coefficient and insolation of the pond. The thick ice-covered days were excluded from the calculation. The maximum value per 2 weeks attained 763g^C/m^2 in summer and the minimum was 27g^C/m^2 in winter. The loss from respiration per 2 weeks attained the maximum of 101g^C/m^2 in summer and the minimum of 0.2g^C/m^2 in winter. These values may be changed according to the variation of dominant species with time in this pond ecosystem. The efficeincy of radiation utilization via net primary production (gross production-respiration) showed the maximum of 11.2% in summer and the minimum of 0.9% in winter and the annual mean value of 6.3%. This value is extremely high in comparision with the values reported from a large part of the oceans (below 1%), but is lower than the values shown during algal culture (12~15%) (Larcher 1980). In an aquatic ecosystem as well as in a terrestrial one, net primary production can be described as inflow to the pool of primary producer's biomass. The inflow per month fluctuated between the maximum of 1190 g^c/m^2 in August 1982 and the minimum of $68g^c/m^2$ in February 1983(Fig. 7). The

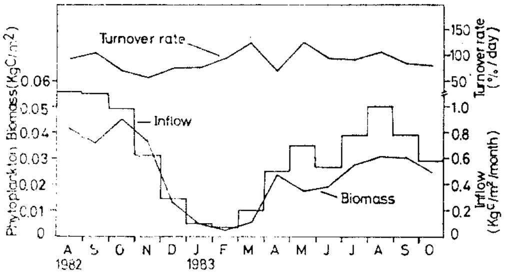

Fig. 7. Seasonal changes of carbon biomass, inflow and turnover rate of inflow rate of phytoplankton community in the Jido pond ecosystem.

carbon of phytoplankton biomass was determined from the assumption that the mean carbon/chl. would be 50 by the data (20～100) of Eppley et al. (1976) and Parsonr et al. (1961). Eppley (1972) reported that the lower extreme was associated with high temperature and low light conditions, and upper extreme was associated with low temperature and high light conditions. Monthly mean phytoplankton biomass of carbon fluctuated between the maximum of $45g^c/m^2$ in October 1982 and the minimum of

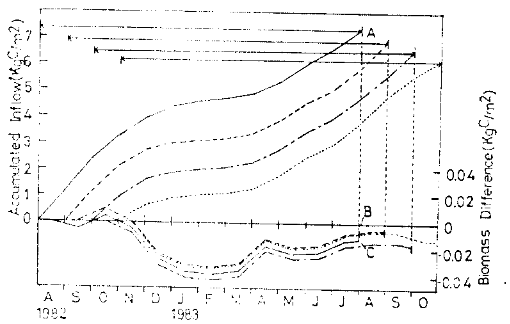

Fig. 8. Accumulated inflows of phytoplankton carbon (upper curves) and differences of the phytoplankton biomass carbon in comparision with the starting month's (lower curves) in the Jido pond ecosystem:———. from August; — — —, from September; —·—·—, from October; ···········, from November 1982. A, B and C; see the text.

$3g^c/m^2$ in February 1983. The turnover rate of inflow rate of phytoplanktonic carbon ranged between 130 and 60%/day with mean value of 90%/day (Fig. 7). Each of the upper curves in Fig. 8 shows a result of the accumulated inflow (net production) of phytoplankton carbon obtained from the different starting month to the 12th month. The differences in phytoplankton biomass carbon from that of the starting month are shown in the lower curves. The distances between A and B and between A and C mean annual inflow ($7.384kg^c/m^2$) and outflow ($7.396kg^c/m^2$) of the phytoplankton community from August 1982 to July 1983, respectively, and the distance between B and C maens the amount of biomass decrement ($0.012kg^c/m^2$) in comparision with the biomass of August 1982. This figure shows an interesting phenomenon that the annual inflow decreased gradually with time.

摘　　要

Phytoplankton이 번성하는 人工池인 지도못에 대해서 1982년 8월부터 1983년 10월까지 水系環境要素및 1次 生産性을 調査하였다. pH, alkalinity, Secchi disc 투과도, 무기질소농도및 phytoplankton 現存量의 변화폭은 각각 7.5～10.6, 50～175mg^{CaCO_3}/l, 24～105cm, 0.1～4.0mg^N/l 및 51～1146mg^{chl}/m^3로서 뚜렷한 계절적 변화를 보였다. phytoplankton 群集의 月間 최대 순생산량은 1982년 8월의 1190g^c/m^2, 최소값은 1983년 2월의 68g^c/m^2였다. 年間(1982.8～1983.7) 순생산량은 7.384kg^c/m^2 손실량은 7.396kg^c/m^2였으며 年平均 태양에너지 이용율및 turnover rate는 각각 6.3% 및 90%/day 였다.

REFERENCES

Banister, T. T., 1974 b. A general theory of steady state phytoplankton growth in a nutrient saturated mixed layer. Limnol Oceanogr., **19** : 13～30.

Brower, J. E. and J. H. Zar, 1977. Field and laboratory methods for general ecology. Wm. C. Brown Comp. Pub., pp.47.

Burnison, B. K., 1980. Modified dimethyl sulfoxide extraction for chlorophyll analysis of phytoplankton. Can.

J. Fish. Aquat. Sci., **37** : 729~733.

Eppley, R. W., 1972. Temperature and phytoplankton growth in the sea. Fish. Bull., **70** : 1063~1085.

______, and P. R. Sloane, 1966. Growth rates of marine phytoplankton: Correlation with light absorption by cell chlorophyll a. Physiol. Plant., **19** : 47~59.

Franson, M. H., 1981. Standard methods for the examination of water and wastewater. APHA, pp.367~387.

Golterman, H L., 1971 a. The determination of mineralization in correlation with the estimation of net primary production with the oxygen method and chemical inhibitors. Fresh Water Biol., **1** : 249~256.

Hickman, M., 1979. Seasonal succession, Standing Crop and determinants of primary productivity of the phytoplankton of Ministic Lake, Alberta, Canada. Hydrobiologia, **64** : 105~121.

Jewson, D. H., B. H. Rippey and W. K. Gilmore, 1981. Loss rates from sedimentation, parasitism, and grazing during the growth, nutrient limitation, and dormancy of a diatom crop. Limnol. Oceanogr., **6** : 1045~1056.

Jones, R. I., 1977. The phytoplankton community and its environment. J. Ecol., **65** : 547~559.

______, 1977. Phytoplankton production and its chief determinants. J. Ecol., **65** : 561~577.

Larcher, W., 1980. physiological plant ecology. Springer-Verlag. New York, p.157.

Parsons, T. R., K. Stephans and J. D. H. Strickland, 1961. On the chemical composition of eleven species of marine phytoplankton. J. Fish. Res. Board Can., **18** : 1001~1006.

Ryther, J. H., 1956 b. The measurment of primary production. Limnol. Oceanogr., **1** : 72~84.

Shoaf, T. W. and B. W. Lium, 1976. Improved extraction of chlorohyll a and b from algae using dimethyl sulfoxide. Limnol. Oceanogr., **21** : 926~928.

Smith, R. A., 1980. The theoretical basis for estimating phytoplankton production and specific growth rate from chlorophyll, light and temperature data. Ecological Modelling, **10** : 243~264.

Strickland, J. D. H. and T. R. Parsons, 1977. A practical handbook of seawater analysis. Fisheries Research Board of Canada, pp.187~192.

Talling, J. F., 1965. Comparative problems of phytoplankton production and photosynthetic productivity in a tropical and a temperate lake. Mem. Ist. Ital. Idrobiol., **18** : 399~424.

(*Received May* 11, 1984)