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Physico-Chemical Environment and Productivity of the Phytoplankton Community in the Jido Pond Ecosystem

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地圖池生態系의 物理化學的環境과 植物性 플랑크톤群集의 生産性

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ABSTRACT

The Jido Pond system was investigated from April, 1979 through March, 1980, in respect of seasonal changes in physico-chemical factors: i.e., temperature, pH, DO, BOD, COD, Cl^-, Mg^{++}, alkalinity, detergent, SiO_2, PO_4^{3-}, NH_4^+, NO_2^-, NO_3^-, total N, OM and OC; phytoplankton community growth; and the ecosystem metabolism. The phytoplankton community was represented by 23 species belonging to Chlorophyta, Bacillariophyta and Cyanophyta; each sharing 11, 9 and 3 respectively. The Chlorophyceans dominated the phytoplankton community contributing 75% of the total algal counts. The ranges of biotic diversity indices were, d, 0.85~2.80; $\bar{H}$, 1.10~2.40; c, 0.13~0.40; and e, 0.56~0.90. The chlorophyll standing crop varied in between 0.043 and 0.385g/cm² surface area. The ranges of photosynthetic and respiratory rates were 0.36~4.50; and 0.10~1.40 O_2 mg/l/hr, respectively. The monthly areal net primary production varied from 23.9 to 305.1C g/m²/month. The Eu of the net production seasonally varied in between 0.31 and 7.80%, and the annual mean was 2.44%. The annual turnover times of phosphorus and nitrogen were 20 and 3 days, respectively.

INTRODUCTION

The present study was aimed at determining seasonal changes of the physico-chemical nature of water and bottom mud nutritional status and nutrient cycling, phytoplankton composition, diversity and succession; standing crop of chlorophyll and primary productivity in an artificially made small shallow fresh-water pond in steady state, located in the Taegu Mountain Valley, which is famous for its unkind climatic extremes in Korea (Fig.1). And to find out the quantitative relationships among themselves and also with the climatic regime. Attempts have also been made to evaluate the trophic status of the pond. The accumulation of these kind of data comprising different parameters interacting together in nature will be useful in understanding inland water systems, especially in terms of generally applicable principles for productivity, which may be helpful for proper utilization and management to human need, Moreover, this artificial pond in natural environment, through long intensive studies may be developed into a model field micro-

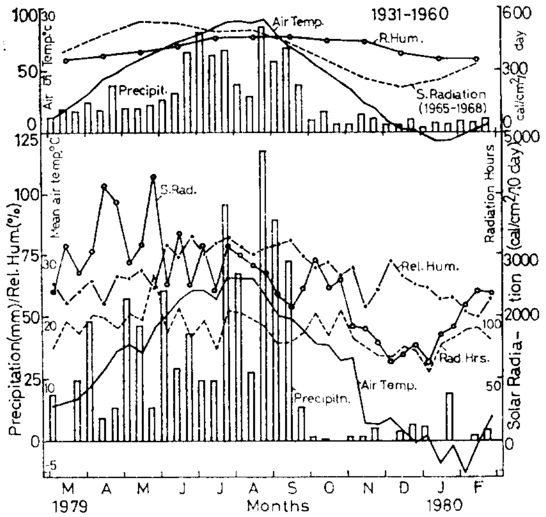

Fig. 1. Seasonal variations of mean air temperature & relative humidity; total solar radiation, precipitation & radiation hours for every 10 days during the Jido Pond ecosystem study (bottom); standard normals of mean air temperature, precipitation & humidity (1931~1960) and solar radiation (1965~1968) at Taegu during the same period(top).

cosm to be used as a reference system for comparing natural inland ponds and lakes, located within a very limited distance of similar geometeorological characteristics.

MATERIALS AND METHODS

The monthly samplings were made from April, 1979 through March, 1980 on the first day of each month, in the morning in between 8 and 10 o'clock. Water samples were collected from a fixed station and at a single depth of 10~20cm below the surface using one liter plastic bottles. The Jido Pond did not stratify and the under surface water sample was considered representative of the whole water column. Bottom mud (sediments) were collceted at the sampling station using a collecting scoop fitted at the end of a wooden rod. Sun light intensities were measured with an illuminometer (SP 1~5), air and water-temperatures were recorded with an approved stem thermometer accurate to 0.1C and pH with a glass electrode pH meter. The samples were taken to the laboratory and analyzed and treated straightway for dissolved oxygen, photosynthesis, respiration, biochemical oxygen demand, chemical oxygen demand, pH and phytoplankton composition. While other samples were stored in the refrigerator for subsequent analyses of mineral nutrients, acidity, alkalinity and biomass standing crop (APHA. 1976).

The biotic or species diversities were calculated as follows:

(1) Index of species richness: $d=S-1/n$ N, where S is the number of species(taxa) per sample and N the total number of individuals (Margalef, 1951).

(2) General or Shannon species diversity: $\overline{H}=-Pi\ ln\ Pi$, where Pi is the proportion of the total sample belonging to the ith species(Shannon & Weaver, 1949).

(3) Evenness or equitability of proportional abundances of the species: $e+\overline{H}/ln$ S,where $\overline{H}$ is the Shannon and Wiever's diversity index and S the number of taxa in the sample (Lloyd & Ghelardi, 1964).

(4) Concentration of dominance: $c=(Pi)^2$, where Pi is the proportion of the total sample belonging to the ith species (Simpson, 1949).

Primary productivity was calculated from the net photosynthetic oxygen production. Solar energy utilization efficiency was calculated after Winberg and collaborators(1972) and Nakanishi(1976). Turnover rates and turnover times of phosphorus and nitrogen were calculated after Golterman(1975).

RESULTS AND DISCUSSION

The pH varied within the range of 7 to 9.4, the highest occuring during summer and autumn. This might be owing to an increased bicarbonate alkalinity due to liberation of ferrous, ammonium and manganous bicarbonate from the sediment during anoxic conditions (Sondergaard *et al.*, 1979), and calcareous formation, which is the characteristic of the local soil type. The netural and near neutral pH was observed during April-May, 1979 and February, 1980. The titration acidity rapidly increased from a low of 1.0 in April to 20 $CaCO_3$mg/l in May but again went down to the undetectable level since July, 1979. The alkalinity marked wide fluctuations from a high value of 82.0 in April to 35.0 $CaCO_3$mg/l in November, maintaining a lowest level during summer-autumn. The dissolved oxygen (DO) content underwent pronounced seasonal variations within the range of 8.0~25.5 O_2 mg/l, which was higher than the standard level, 5.0mg/l, for protection of aquatic life. As would be expected, the seasonal changing pattern was characterized by a gradual rise from April through summer and autumn to the highest level in winter. The biochemical oxygen demand (BOD^{25}_{5}), which reflects the organic matter available for bacterial oxidation, fluctuated between 3.7 and 17.8mg O_2/l. The BOD starting with 3.7mg O_2/l in April, 1979, steadily increased to a peak of 14.1mg O_2/l in July, then rapidly decreased to 6.2mg O_2/l in August, which was again followed by gradual rises through autumn and winter ultimately attaining the annual highest peak of 17.8mg O_2/l in March. The chemical oxygen demand (COD), which reflects the organic loading of the waters, fluctuated in between 3.7 and 46.8mg O_2/l, marking two peaks, one of 46.4mg O_2/l in early summer and another of 46.8mg O_2/l in late winter, with a intervening low of 29.7mg O_2/l in autumn. These values are also much higher than the usual permissible level in drinking waters. The seasonal variation ranges for NH_4-H, NO_2-N and NO_3-N were 0.14 to 3.50, 0.03 to 0.21 and 0.03 to 1.25ppm, respectively. The ammonium maximum at the surface is not easily understood, but might be related to increased zooplankton activity, decreased algal uptake, or an increased supply from the atmosphere. NO_2-N marked the highest level of 0.21ppm in summer, which was followed by lowest levels with little fluctuations all through the other seasons. The NO_3-N attained the annual highest level of 1.25ppm in winter, a low in spring and the lowest levels with almost no fluctuation through the other seasons. The PO_4-P varied within the very narrow range of 0.50~0.66ppm with two peaks, each of 0.66, one in late summer and the other in winter. This concentration level was much lower than the total dissolved nitrogen in the pond water. The SiO_2-Si showed a pronounced seasonality in respect of concentrations, ranging from 5 to 31 ppm during the study period. The highest annual peak appeared in autumn besides two smaller peaks in April and July. Magnesium concentration also showed pronounced seasonality, ranging from 8.3 to 43.5mg/l. The detergent concentrations in the pond water fluctuated conspicuously between 1.3 and 10.0ppm, starting with a smaller peak of 4.4ppm in late spring, gradually declined to the lowest level in late summer, but ultimately attained the annual highest level in winter. The chloride concentration fluctuated within a limited range of 24.0 to 52.5mg /l, which also corresponded with the seasonal precipitation. The NH_4-N seasonally varied widely in between 0.3 and 19.0ppm, attaining higher peaks of 19.0 and 18.0ppm, respectively in June and September, 1979 with an intervening low of 14.7ppm. The autumn-winter maximum was 5.1ppm in December. The NO_2-N revealed remarkable seasonal variations within the limit of 0.03 to 1.04ppm, attaining the highest level in June, which then declined rapidly to lowest levels during late summer through spring. This changing pattern exactly corresponded to that of NO_2-N in water. The NO_3-N showed highly fluctuating seasonal variations of all the dissolved elements both in the mud and water, ranging in between 0.006 and 0.563ppm. This changing pattern, excepting the correspondence of the highest peak in winter, largely differed from that in water. The total nitrogen content. like the nitrate nitrogen, marked zig-zag seasonal fluctuations within the limited range of 0.15 to 0.31% on dry weight basis. Soil organic matter(OM) underwent remarkable changes ranging from 5.9 to 27.3% on a dry weight basis. The highest value appeared in autumn. Organic carbon(OC) content showed marked fluctu-

Table 1. Time trend of the species composition density of the phytoplankton community in the Jido Pond ecosystem (April, 1979 through March, 1980)

Phytoplankton	Mean numbers of algal units counted per mm^3 on each sampling occasion											
Division Species	1979				Months					1980		
	4	5	6	7	8	9	10	11	12	1	2	3
Chlorophyta: *Chlorella vulgaris*	105	31	52	109	354	203	63	8	10	42	151	43
Scenedesmus quadricauda	14	16	18	16	21	19	45	72	109	15		
Chlamydomonas angulosa	16	10			5	10	16	10				5
Golenkinia paucispina				20	125	333	224	161	47	31	47	78
Pediastrum simplex					5	21	10	5				
Botrycoccus sudeticus					21							
Kirchneriella contorta					5	6	12					
Ankistrodesmus falcatus						21				78	31	52
Phytoconis sp.						5	22	38	68	218	109	36
Hematococcus lacustris							16	15	16	13	64	55
Coelastrum microporum							41					
Bacillariophyta: *Synedra* sp.	16	16	10								16	
Navicula cryptocephala	15	16	16	13	14	10	21					
Fragilaria crotonensis	38	5		10	20	10	16					52
Diatoma vulgare	10					5	16	19	26	33	58	5
Nitzschia linearis	12										15	27
Pinnularia viridis				11	18	26	12	10				
Cyclotella Meneghiniana							33	48	47	31	26	
Hydrosera sp.							16					
Asterionella sp.				5		10	9					
Cyanophyta: *Gomphosphaeria lacustris*		43	11		10		18	5				37
Oscillatoria tenuis						5	25		31	57	78	
Anabaena planktonica						7	10	13	11		6	

ations ranging from 2.4 to 7.2%. The highest content was in March and the lowest levels were in spring and autumn. The PO_4-P in the sediments revealed seasonal variations to the extent of 0.52 to 1.60ppm, the highest being more than double to that of water. The highest peak of 1.6ppm was attained in spring, the second peak of 1.20ppm was in late summer, and the subsequent variations were within the limit of 0.52~0.82ppm during autumn and winter. Phosphate content in the sediment althrough maintained a higher level than that in water. The phytoplankton community in the Jido Pond, through the study, was represented by 23 species belonging to three major groups of algae: Chlorophyta, Bacillariophyta and Cyanophyta, each sharing 11, 9 and 3 species, respectively (Table 1). Chlorophyta was represented by *Chlorella vulgaris*, *Scenedesmus quadricauda*, *Chlamydomonas angulosa*, *Golenkinia paucispina*, *Pediastrum simplex*, *Botrycoccus sudeticus*, *Kirchneriella contorta*, *Ankistrodesmus falcatus*, *Phytoconis* sp., *Hematococcus lacustris* and *Coelastrum microporum*. The Bacillariophyta was represented by *Synedra acus*, *Navicula cryptocephala*, *Fragilaria crotonensis*, *Diatoma vulgare*, *Nitzschia linearis, Pinnularia viridis, Cyclotella meneghiniana, Hydrosera* sp. and *Asterionella gracillima.* While the Cyanophyta was represented by *Gomphosphaeria lacustris, Oscillatoria tenuis* and *Anabaena planktonica.* Several factors might have been involved for the small population size during spring. This might be partly attributed to the comparatively low level of DO. Since low DO concentration reduce the efficiency of oxygen uptake by many aquatic organisms, thereby reducing their ability to meet other environmental demands.

The ranges of diversities and annual averages were 0.85～2.80 and 1.54 for *d*, 1.10～2.40 and 1.72 for $\bar{H}$, 0.13～0.40 and 0.24 for *c*, and 0.56～0.90 and 0.76 for *e*. Since the diversity values are primarily dependent on the number of species, the seasonal and areal variations of the diversity values are very reminiscent of the variations in the number of species, especially in cases of *d* and $\bar{H}$ values. The maxima of $d, \bar{H}$ and to some extent *e* corresponded with the minimum of *c* in autumn, while the maximum of *c* corresponded with the minima of $d, \bar{H}$ and *e*, during the spring-summer overturn. (Fig. 2).

The seasonal changes in the production of chloro

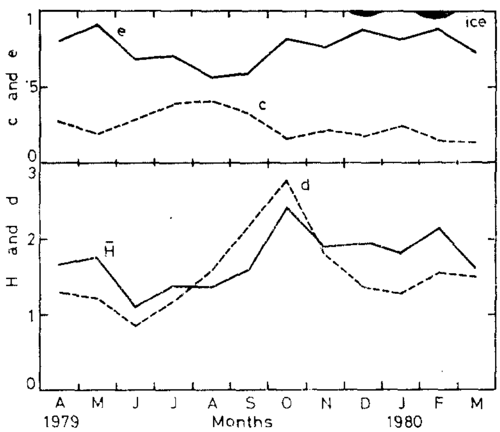

Fig. 2. Biotic (or species) diversity indices of the phytoplankton community in the Jido Pond ecosystem: Shannon diversity ($\bar{H}$), index of species richness (*d*), concentration of dominance (*c*) and evenness of proportional abundances of species (*e*).

-phyll (total) standing crop were within the range of 0.043 to 0.385g/m² surface area (Fig.3).

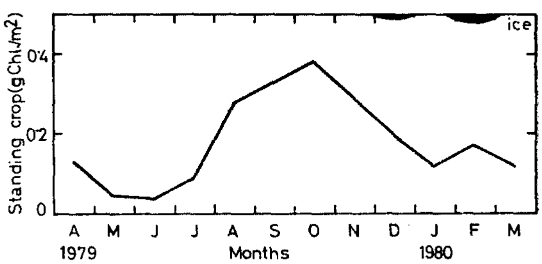

Fig. 3. Time trend of the chlorophyll standing crop of the phytoplankton community in the Jido Pond ecosystem.

As a prerequisite to study the phytoplankton productivity in a site, the photosynthetic and respiratory characteristics were followed, since algal photosynthesis is the product of the total ecosystem. Throughout the study, the photosynthetic, ***in vitro***, rates varied within the range of 0.36～4.50mg/*l* (Fig. 4).

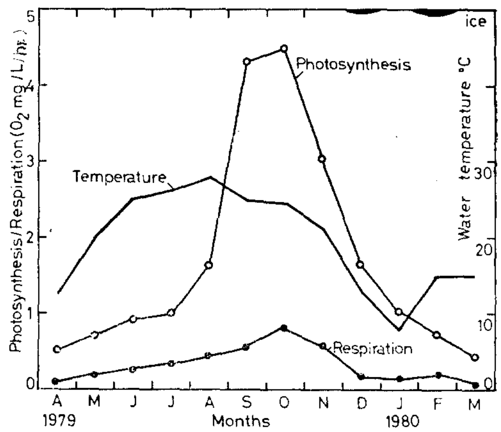

Fig. 4. Time trends of the ***in vitro*** rates of photosynthesis and respiration by the phytoplankton community in the Jido Pond ecosystem.

The seasonal highest values of 4.30 and 4.50mg O_2/l were, respectively attained in September and October, while March had the annual lowest rate. The assimilation number (that is, photosynthetic index), as calculated by converting photosynthetic oxygen quantity to carbon assimilation by the phytoplankton, varied seasonally within the range of

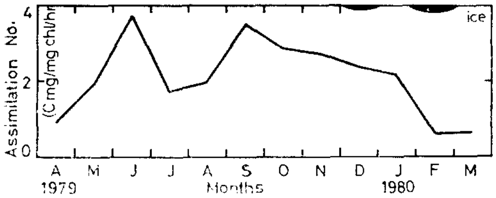

Fig. 5. Time trend of assimilation number of the phytoplankton community in the Jido Pond ecosystem.

0.6 to 3.8mg C/mg chl/hr (Fig. 5). The monthly areal net primary production values ranged from 23.9 to 305.1C g/m^2/month for the phytoplankton community, and that on the annual basis was 967.9C g/m^2.

The efficiency of the net production seasonally varied within the range of 0.6 to 7.8%, and the annual mean was 2.44% (Fig. 6). From the $C_5H_7NO_2P_{1/30}$ composition of algal cell protein, the total annual demand for phosphorus and nitrogen by the Jido Pond phytoplanktons were calculated for the total annual net primary production against respective standing quantities of phosphate-phosphorus and total dissolved nitrogen in the entire water column. Accordingly, the turnover time ("biological turnover time") of phosphorus was calculated to be 20 days, and the turnover rate was 18g, on annual basis. According to the bases of the phosphorus calculation, stated above, nitrogen turnover was calculated for the Jido Pond water body. The nitrogen turnover period was 3 days and the turnover rate was 116g, on annual basis.

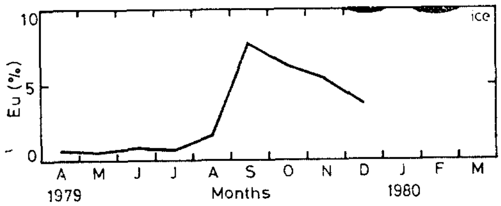

Fig. 6. Time tren l of the efficiency of solar energy utilization (Eu) by the phytoplankton community in the Jido Pond ecosystem.

摘　要

人工池인 地圖池生態에 대하여 1979年 4月부터 1980年 3月까지 水溫, pH, Cl^-, Mg^{++}, alkalinity, detergent, SiO_2-Si, PO_4-P, NO_3-N, NO_2-N, NH_4-N, BOD, COD, DO, OM 및 OC등의 物理化學的 水質環境의 動態를 分析하고 一次生產者인 植物性플랑크톤의 多樣性 및 生長과 生產性을 測定하여 生態系의 物質代謝와 에너지利用効率을 定量化하였다. 植物性플랑크톤의 分布는 總28種의 優占種(Chlorophyta 11種, Bacillariophyta 9種 및 Cyanophyta 3種)이 出現하였고, chlorophyta는 全體 algal counts의 75%를 점하였다. 多樣性指數는 d=0.85～2.80, $\overline{H}$=1.10～2.40, c=0.12～0.40, e=0.56～0.90였다. 現存量은 0.043～0.385g chl/m^{2}의 範圍었고, 光合成率 및 呼吸率의 變化는 각각 0.36～4.50와 0.10～1.40mg O_2/l/hr이며, 同化量은 0.6～3.8mg C/mg chl/hr로서 月別의 一次生產性은 23.9～305g C/m^2, 太陽에너지 이용효율은 年平均 2.44%였다. 燐과 窒素의 turnover time은 각각 20days와 3days였다.

REFERENCES

American Public Health Association (APHA), 1976. Standard methods for the examination of water and waste water.

Golterman, H. L., 1975. Physiological Limnology (First Edn). Elsevier Scientific Publishing Company-Amsterdam., pp. 489.

Lloyd, M. and R. J. Ghelardi, 1964: A table for calculating "equitability" component of species diversity. J. Anim. Ecol., 33 : 217～225.

Margalef, R., 1951. Diversidad de especies en las comunidades naturales. Proc. Inst. Biol. Apl., **9** : 5～27.

Nakanishi, M., 1976. Seasonal variations of chlorophyll *a* amounts, photosynthesis and production rates of macro-and microphytoplankton in Shiozu Bay, Lake Biwa. Physiol., Ecol. Japan., **17** : 535～549.

Shannon, C. E. and W. Weaver, 1949. The mathematical theory of communication. Urbana. pp. 117.

Simpson, E. H., 1949. Measurement of diversity. Nature, **163** : 688.

Sondergaard, M. and K. Sand-Jensen, 1979. Physico-chemical environment, phytoplankton biomass and production in oligotrophic, softwater Lake Kalgaard, Denmark. Hydrobiologia, **63**(3) : 241～253.

Winberg, G. G. and Collaborators. 1972. Symbols, units and conversion factors in studies of freshwater productivity. pp. 23. IBP Central Office, London.

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