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EFFECTS OF THE SUMMER MONSOON ON THE DISTRIBUTION AND LOADING OF ORGANIC CARBON IN A DEEP RESERVOIR, LAKE SOYANG, KOREA

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Abstract—Seasonal and vertical patterns of organic carbon concentration, and an organic carbon budget were studied in a deep reservoir in Korea. Dissolved organic carbon (DOC) and particulate organic carbon (POC) were measured in the river inflow and at the dam. Autochthonous production of carbon was estimated from phytoplankton primary productivity. Variations in POC were greater than for DOC, reflecting pronounced changes in algal biomass during the study period. Before the monsoon, in spring and early summer, DOC concentrations consistently were low (*ca.* 1.5 mg l^{-1}). Heavy rains associated with the summer monsoon had substantial impacts on the lake's carbon budget. Turbid storm runoff supplied large quantities of nutrients and organic carbon to the metalimnion. Some of these substances were advected into the epilimnion, and may have contributed to a seasonal increase in primary productivity. Although annual rates of carbon supply from allochthonous and autochthonous sources were similar, the autochthonous carbon appears to be a more important energy source in the lake because most allochthonous carbon was discharged from the dam without affecting the epilimnion.

Key words—DOC, POC, primary production, summer monsoon, Lake Soyang

INTRODUCTION

The quantity of organic matter that enters a lake ecosystem per unit of time sets an upper limit on the amounts of biomass and productivity that can be attained. Organic matter can be estimated by measuring carbon because all organic matter contains reduced carbon atoms. Photosynthetic production of organic matter also is commonly measured in units of carbon. The concentration of organic carbon is readily measured using automated methods (Jørgensen, 1986), and generally is expressed as the sum of DOC and POC (Thurman, 1985).

In aquatic ecosystems, the majority of organic carbon is in the form of DOC, while POC typically contributes only 10–17% of the total (Wetzel, 1983; Thurman, 1985). However, it has been reported that the ratio of DOC:POC can vary with season, depth, and trophic state of the lake. This variation depends more on changes in POC concentration than on changes in DOC (Thurman, 1985). In eutrophic and mesotrophic lakes, phytoplankton accounts for most of the POC, and when the production of phytoplankton increases, so does the ratio of DOC:POC (Seki and Nakano, 1981; Thurman, 1985). In oligotrophic lakes, abiotic seston may account for a greater portion of the POC pool.

Strong relationships between DOC concentration and the standing crop and species composition of phytoplankton also have been reported. For example, it has been observed that DOC is highest during the spring and late summer, coincident with blooms of cyanobacteria (Hama and Handa, 1983; Fukushima *et al.*, 1996). Diel fluctuations in DOC concentration also have been observed, with a rapid increase from morning to late afternoon and a gradual decrease after sunset (Kaplan and Bott, 1982; Søndergaard and Schierup, 1982). Wetzel (1972) noted that vertical heterogeneity of DOC concentrations also could occur, with higher levels in the epilimnion than in the hypolimnion, especially during summer stratification. In contrast, Hama and Handa (1983) reported that vertical heterogeneity was not significant in shallow Lake Suwa, Japan. DOC distribution also can be affected by water mixing and various biological processes (Guo *et al.*, 1995).

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The organic carbon in lake water has two sources: allochthonous and autochthonous (Wetzel, 1983). The relative contribution of these sources to the lake carbon budget depends on hydraulic retention time, development of the littoral zone, and trophic state. With progressing eutrophication autochthonous carbon becomes increasingly important. However, allochthonous carbon from the watershed can substantially impact the lake carbon budget (regardless of trophic state) during periods of intense rainfall when hydraulic residence time is short. During periods of intense rainfall POC loading from a river may be dramatically increased, because the suspended load increases as the flow of the river increases (Wetzel and Manny, 1977; Nemeth *et al.*, 1982; Thurman, 1985). DOC loading also can increase by 50–100% of average amounts (Thurman, 1985).

There are many studies of organic carbon cycling in natural lakes and rivers, but few have considered deep reservoirs. Lakes of this type are common in many developed regions of the world, because they are constructed for flood control, power generation, and water supply purposes. In some nations they account for a large percentage of surface waters, and therefore it is important to understand their limnology. In the present study we determined the factors controlling seasonal and vertical distributions of POC and DOC in deep Lake Soyang, Korea, and estimated loads and likely origins of organic carbon to the lake.

STUDY AREA

Lake Soyang (Fig. 1, Table 1) is the deepest and largest reservoir in Korea; it was constructed on the North Han River in 1973. The lake has one main inflow, the Soyang River, which contributes 90% of the inflow water volume. The hydraulic retention time is the longest in Korea (*ca.* 0.7 y) because the inflow rate is small compared with the lake's large volume. A few small towns occur in the watershed, and there is little influence of industrial sewage. Most of the lake's nutrient loading is from nonpoint agricultural sources and from net cage-type fish farms located within the lake. Annual precipitation in the region of the lake is 1200 mm y^{-1}. More than half of this input occurs during the summer monsoon season in July and August, when rainfall is concentrated in several episodic heavy showers of >100 mm d^{-1}. Therefore the maximum ratio of stream discharge on rainy vs dry days is $>300{:}1$. A wide range of water level fluctuations suppresses the development of a macrophyte com-

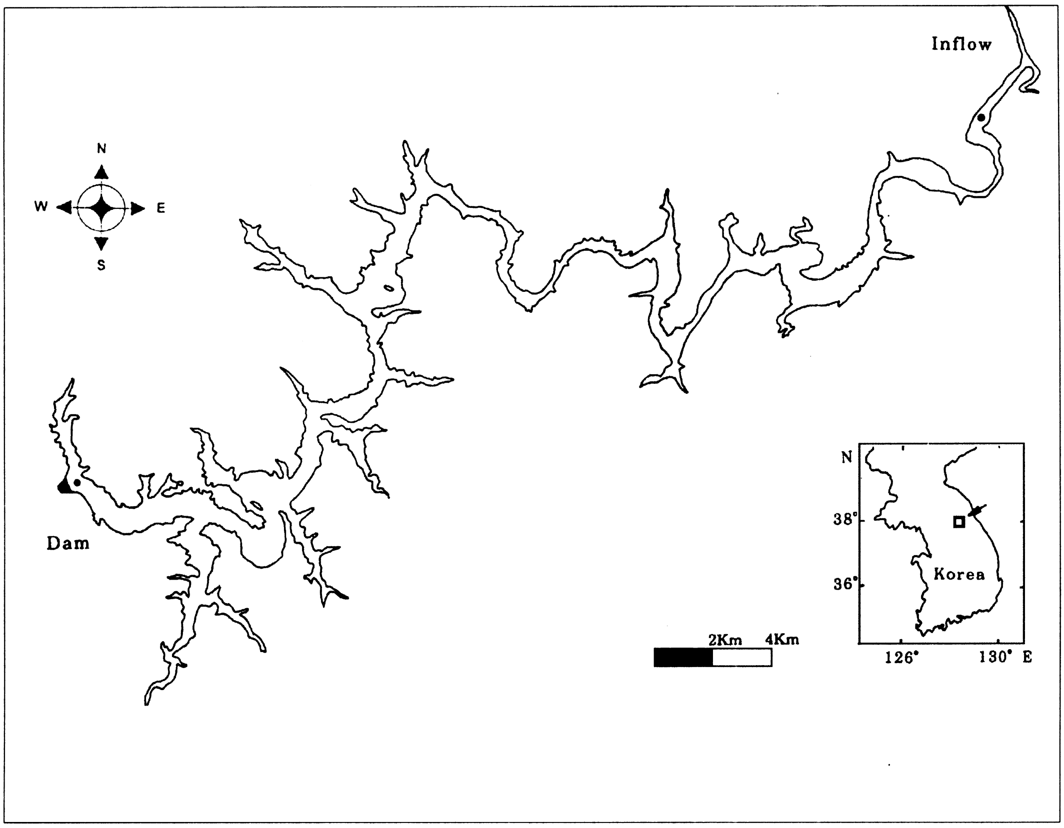

Fig. 1. Map showing sampling stations in Lake Soyang.

munity in the lake, and as a result, nearly all of the autochthonous organic carbon is produced by phytoplankton.

METHODS

Samples were collected at depths of 0, 2, 5, and at 10 m intervals up to 100 m at the dam site at one or two week intervals from May 1995 to February 1997. The samples from May, June, and August 1995 and November 1996 were collected only at the upper layer, from 0 to 20 m or 30 m. For the interpretation of data, we divided strata of the lake into three layers according to depth of the intermediate layer of storm runoff. The upper layer was from 0 to 10 or 20 m; the middle layer was from 20 to 50 or 60 m; and the bottom layer was below 60 or 70 m. Surface samples from the Soyang River were collected at weekly intervals during the dry season, and three or four times per day during the monsoon season, when water quality varied largely with the discharge rate.

Water samples for DOC and POC analyses were filtered through pre-combusted (450°C), Whatman GF/F filters. The filters were dried for 1 h at 50°C before measuring POC concentration. The filtrate, used for DOC measurement, was collected directly in an acid-cleaned, pre-combusted (550°C) glass bottle with a Teflon-lined cap, and frozen at −20°C. Chlorophyll *a* samples were filtered through separate Whatman GF/C filters, which also were stored frozen until analysis.

The concentration of DOC was measured by the HTCO method using a Shimadzu 5000 total carbon analyzer with 2.8 g of a 20% Pt catalyst on quartz wool. Analytical precision typically was ±1% based on three or more measurements of each sample. POC concentration was measured using a Yanaco MT-5 CHN analyzer. Filters for chlorophyll *a* analysis were ground in a tissue homogenizer with 6 ml of 90% acetone and centrifuged to remove turbidity. Concentrations of chlorophyll *a* were determined by the method of Lorenzen (1967). Phytoplankton primary productivity was determined from photosynthesis–irradiance (P–I) curves measured using the ^{14}C-uptake method described by Kim (1987)

Allochthonous carbon loading to the lake was calculated from the daily inflow rates multiplied by the concentrations of organic carbon in the water, and the autochthonous loading was obtained from the monthly measurements of areal productivity multiplied by the lake surface area. Water inflow, rainfall, and outflow data were obtained from the from Korea Water Resources Corporation (KOWACO) and the Chunchon Meteorological Service.

RESULTS

Seasonal variations of POC and DOC with flow rate in the Soyang River

Most of the rainfall during the study period was concentrated during heavy showers in July and August (Fig. 2a); inflows responded quickly to these short-term rainfall events (Fig. 2b). POC concentrations in the Soyang River varied from 0.3 to 4.6 mg l^{-1}, and corresponded closely with variations in flow rate (Fig. 2c). POC maxima occurred during the summer monsoon when the water was turbid. No increases in POC were observed unless rainfall amounts exceeded 50 mm. During the dry season, the river displayed nearly constant levels of POC (*ca.* 0.5 mg l^{-1}). Concentrations of DOC displayed more variation during the dry season (Fig. 2d) and large increases with flow in the monsoon season. In certain cases, when rainfall, inflow, and POC increased (e.g., August 24, 1995), DOC did not increase.

Seasonal and vertical variation of POC and DOC concentrations in Lake Soyang

POC concentration was vertically homogeneous, except from July to October (Fig. 3). In the upper layer, POC gradually increased during this period, with maximal concentrations occurring in September of 1995 and 1996 (1.6 and 1.1 mg l^{-1}, respectively). As winter approached, POC concentration in the upper layer decreased to 0.1 mg l^{-1}. In the middle layer, POC concentration also was highest during summer, increasing to 1.0 mg l^{-1} on September 22, 1995 and 2.4 mg l^{-1} on August 10, 1996. In the bottom layer, POC concentration usually was greatest at the maximal sampling depth.

DOC concentration was consistently near 1.5 mg

Table 1. Hydrological characteristics and utilization of drainage basin of Lake Soyang. Yearly average records from 1995 to 1997

Function	Water supply in dry season Flood control Hydroelectric power generation
Shape	Dendritic
Circulation type	Warm monomitic
Trophic state	Meso-eutrophic
Surface area (km^2)	45
Water capacity (m^3)	2.9×10^9
Yearly average inflow (m^3 s^{-1})	2.1×10^9
Yearly average outflow (m^3 s^{-1})	2.1×10^9
Maximum depth (m)	110
Water surface elevation (m)	165–195
Mean depth (m)	42
Hydraulic residence time (y)	0.7
Length of main axis (km)	60
Mean width (m)	750
Drainage area (km^2)	2675
Urban area in drainage basin (km^2)	1
Paddy area in drainage basin (km^2)	163
Forest and mountain area (km^2)	2563
Total population in drainage area (persons)	52,577

l^{-1} in the spring and early summer before the monsoon (Fig. 3). After the monsoon season, DOC concentration in the upper layer increased and reached its peak in September 1995 and 1996, coinciding with the occurrence of cyanobacterial blooms. High DOC concentrations persisted in the upper layer until January. In the middle layer, DOC also was high during the monsoon season and afterwards. In the bottom layer, DOC increased after the summer.

DOC:POC ratio

The ratio of DOC:POC at the dam site varied from 0.8 to 60 (mean = 9, n = 171). The ratio was below 10 from spring to autumn. It decreased to 0.8 in the middle layer in August 1996 due to the inflow of turbid storm runoff. The ratio also was low in the surface layer during September 1995 coincident with increased POC and the phytoplankton bloom. In 1995, the ratio increased from November to January (to > 60).

At the river site the ratio of DOC:POC varied from 1 to 10 (mean = 4, n = 109) and generally it was lower than at the dam. During the summer monsoon season the ratio was < 1. Except for this period, the DOC:POC ratios measured in the river and at the dam were similar to those measured in

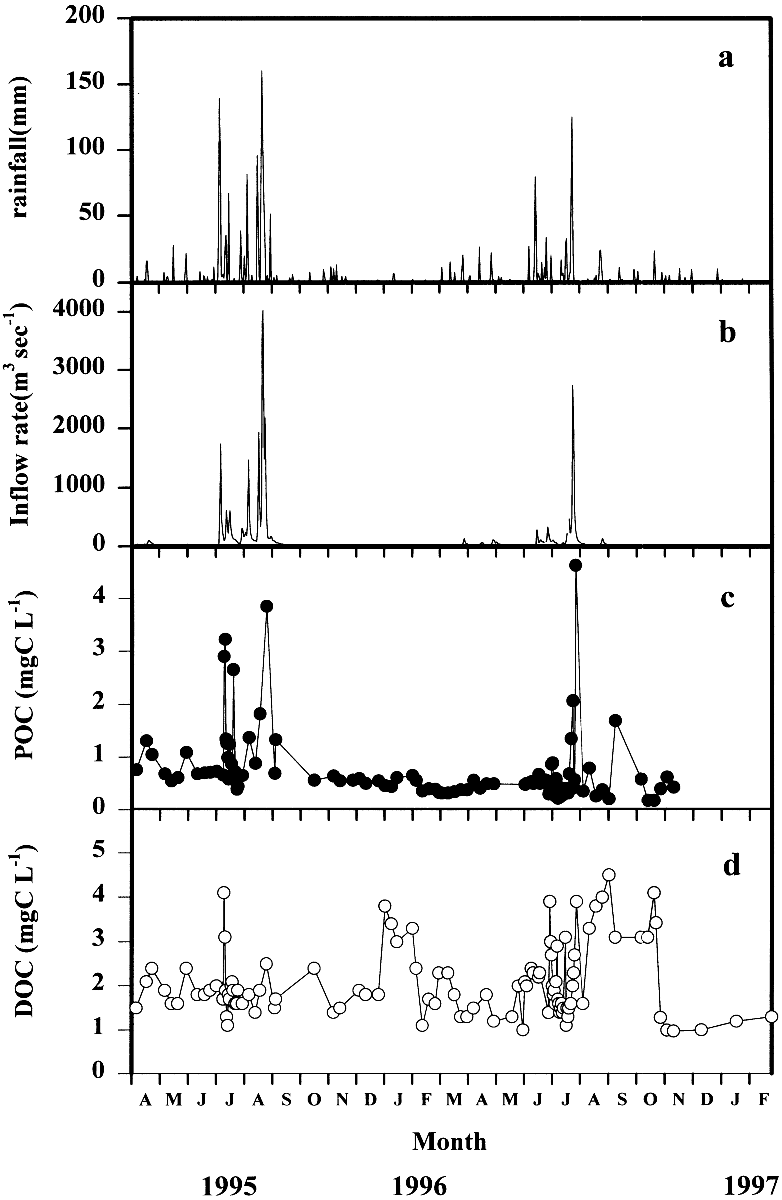

Fig. 2. Seasonal variations of rainfall, flow rate, and organic carbon concentration in the Soyang River, from April 1995 to February 1997.

other rivers and lakes of the world, where the typical range is from 6 to 10 (Wetzel and Rich, 1973; Thurman, 1985).

Relationships between chlorophyll a, POC, and DOC concentrations

Chlorophyll *a* concentrations in the upper layer at the dam site were very high in September, when cyanobacterial blooms occurred (Fig. 4). The chlorophyll *a* maximum in 1995 was threefold higher than in 1996. Chlorophyll *a* concentrations also increased somewhat during a spring diatom maximum (March 1996), but not to the degree observed during the cyanobacterial blooms. Primary productivity also was elevated during summer (393–2250 mgC m^{-2} d^{-1}) and low in winter (34–644 mgC m^{-2} d^{-1}) (Fig. 4). Productivity peaks corresponded with maximal amounts of chlorophyll *a*. The POC concentration also varied with chlorophyll *a*. Peaks of POC and DOC occurred during the late summer blooms in 1995 and 1996 (Fig. 4). As winter approached, POC concentration decreased along with decreases in phytoplankton. The concentration of DOC decreased rapidly in autumn 1996, whereas in 1995 the more intense algal bloom might have maintained high DOC concentrations until January.

The slope of a least-squares regression model of POC vs chlorophyll *a* was taken as an approximation of the POC:chlorophyll *a* ratio. This ratio was 43 in 1995 and 77 in 1996 (Fig. 5). These values are similar to those reported in previous studies,

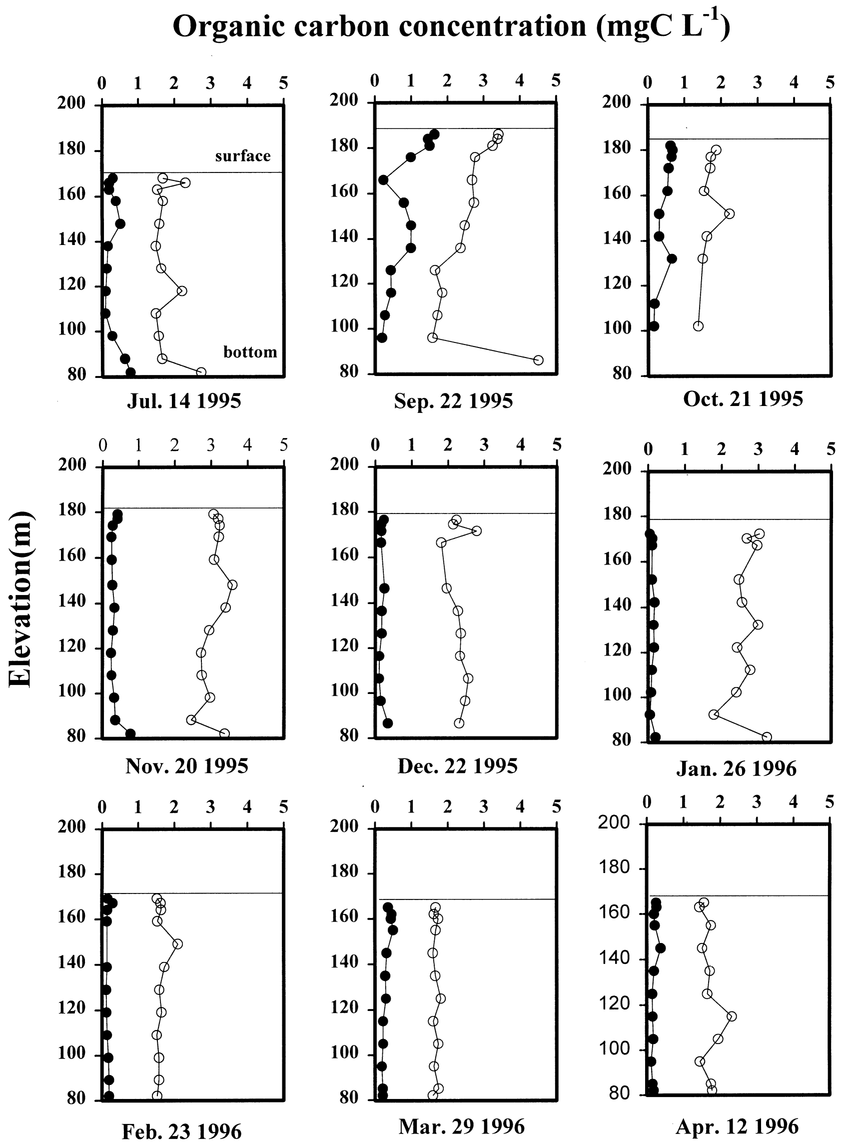

Fig. 3. Seasonal variation of organic carbon concentration at the dam site of Lake Soyang, from July 1995 to February 1997 (●: POC, ○: DOC).

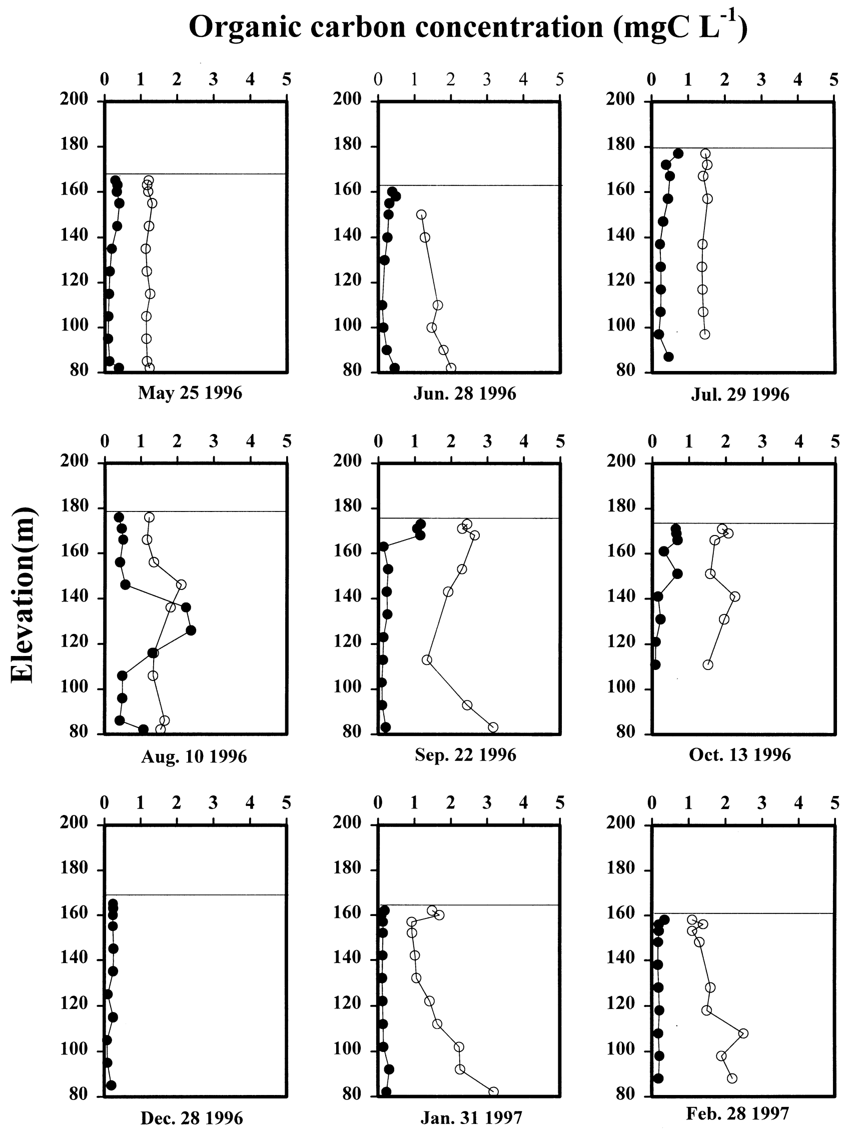

Fig. 3 (*continued*).

including 65 in Lake Kasumigaura (Japan) during summer and autumn (Aizaki & Otsuki, 1987) and 50 in Lake Frederiksborg Slotssø (Europe) during autumn (Riemann *et al.*, 1989). In both cases, cyanobacteria were the dominant phytoplankton taxa.

Chlorophyll *a* and DOC were not significantly related, even though it has often been reported that the growth of phytoplankton contributed to the DOC pool by excretion (Mague *et al.*, 1980; Jørgensen, 1986). DOC leaching from dead algae also is known to contribute to the DOC pool of lakes (Hansen *et al.*, 1986).

Organic carbon loading into Lake Soyang

During this 22-month study, about 90% of the allochthonous carbon loading to Lake Soyang from its watershed was concentrated during the summer monsoon season in July and August (Table 2). Carbon loading was especially high during periods of heavy rainfall. The largest monthly rate of TOC loading (9140 metric tons) occurred in August 1995 when the amount of rainfall was highest. Monthly DOC loading comprised 56–96% of the TOC loading during the dry seasons. However, the total DOC loading over 22 months (9803 metric tons) was only 46% of the total TOC loading (21,163 metric tons). At this time we have only a rough estimate of the amount of organic carbon loading from fish farms inside the lake, based on the annual feed supply rate of 900 metric tons y^{-1}.

Autochthonous organic carbon production by

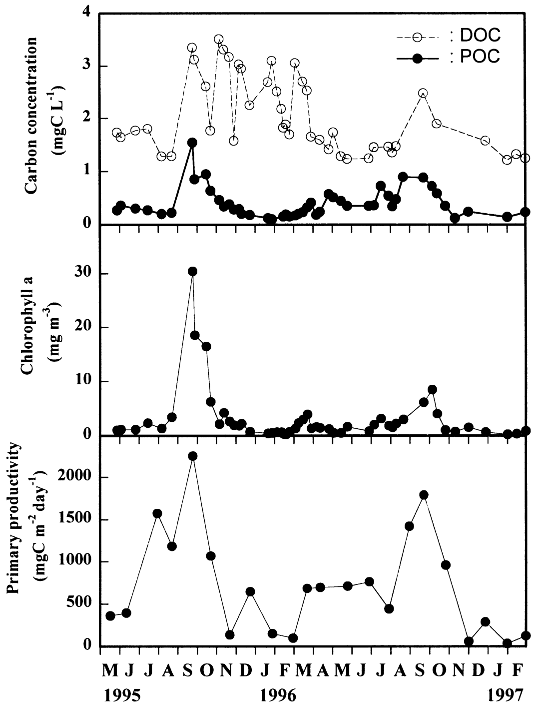

Fig. 4. Monthly variations of DOC, POC, chlorophyll *a* concentration, and primary productivity in the upper layer of Lake Soyang, from May 1995 to February 1997.

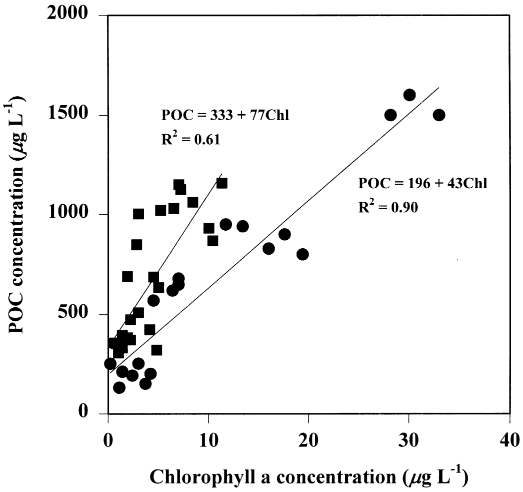

Fig. 5. Plot of POC vs chlorophyll *a* concentration of euphotic zone in Lake Soyang during cyanobacterial blooms, from August to September (●: 1995, ■: 1996).

phytoplankton varied greatly (Table 2). This internal source was highest from July to October in 1995 and from August to October in 1996, and was negligible during winter. The peak of allochthonous carbon loading occurred during the summer monsoon season, whereas the peak of autochthonous loading occurred in September, about one month after the monsoon.

During the study period total allochthonous (excluding fish farms) and autochthonous organic carbon loading were 21,163 and 21,411 metric tons, or 47.9% and 48.5% of total loading, respectively. According to the source, however, monthly loading was significantly different depending on season. In the summer monsoon season, allochthonous loading from the watershed greatly exceeded autochthonous

Table 2. Monthly loadings of allochthonous and autochthonous organic carbon (ton C month^{-1}) in Lake Soyang. Within the parentheses are the percentage of each contribution to total loading

Month	Allochthonous				Autochthonous phytoplankton	Total loading
	Watershed			Fishfarm		
	DOC	POC	TOC			
May 1995	95	32	127 (20.2)	100 (15.9)	402 (63.9)	629
June	72	28	100 (16.3)	100 (16.3)	413 (67.4)	613
July	1425	1116	2541 (56.0)	100 (2.2)	1899 (41.8)	4540
August	4006	5134	9140 (80.7)	100 (0.9)	2089 (18.4)	11,329
September	262	159	421 (9.6)	100 (2.3)	3848 (88.1)	4369
October	85	26	111 (5.7)	100 (5.1)	1748 (89.2)	1959
November	109	22	131 (30.3)	100 (23.2)	201 (46.5)	432
December	37	9	46 (4.7)	0	938 (95.3)	984
January 1996	42	7	49 (19.9)	0	197 (80.1)	246
February	13	3	16 (12.6)	0	111 (87.4)	127
March	50	11	61 (6.6)	100 (10.9)	761 (82.5)	922
April	136	43	179 (17.4)	100 (9.7)	751 (72.9)	1030
May	108	41	149 (14.3)	100 (9.6)	791 (76.1)	1040
June	250	64	314 (26.9)	100 (8.6)	754 (64.5)	1168
July	2390	4513	6903 (90.1)	100 (1.3)	656 (8.6)	7659
August	406	106	512 (20.5)	100 (4.0)	1889 (75.5)	2501
September	201	8	209 (8.2)	100 (3.9)	2254 (87.9)	2563
October	59	6	65 (4.8)	100 (7.4)	1188 (87.8)	1353
November	21	10	31 (15.7)	100 (50.5)	67 (33.8)	198
December	15	9	24 (7.1)	0	314 (92.9)	338
January 1997	10	6	16 (32.0)	0	34 (68.0)	50
February	11	7	18 (14.5)	0	106 (85.5)	124
Total	9803	11,360	21,163 (47.9)	1600 (3.6)	21,411 (48.5)	44,174

loading, whereas during the dry season autochthonous loading was higher than allochthonous (Table 2).

DISCUSSION

In the Soyang River, the average DOC concentration was 2 mg l^{-1} during the dry season, which is lower than the world average of 6 mg l^{-1} and the average of 7 mg l^{-1} observed in rivers of temperate climates (Thurman, 1985). The mean POC concentration of 0.5 mg l^{-1} during the dry season also was lower than the world river average of 2 mg l^{-1} (Meybeck, 1982). In the Soyang River, DOC was the major part of organic carbon during the dry season and the ratio of DOC:POC was about 5. During the summer monsoon season the ratio decreased to 1, coincident with increased particle loading from the watershed. Several heavy rainfall events typically occur during summer in Korea, they result in intensive loading of organic matter as well as nutrients from watersheds. Much of the organic matter that accumulates in the watershed during the dry season is exported during the first heavy rain, which often can amount to more than 100 mm d^{-1}. A similar phenomenon was observed by Parks and Baker (1997) in the Salt River of Arizona, where every year a distinct peak of TOC loading occurred during the late summer, coincident with abrupt increases of flow rate. In Lake Soyang, POC concentration increased up to 10-fold during storm runoff events, but DOC was less affected. In the summer monsoon season, a decreased ratio of DOC:POC occurred, and this likely was due to the increased inputs of POC. Nemeth *et al.* (1982) reported that POC was 0.5 mg l^{-1} in the dry season and 9 mg l^{-1} in the rainy season in the Orinoco River of Venezuela, where the increase of DOC also was smaller than POC. Similar results have been reported in other studies (e.g., Wetzel and Manny, 1977; Dahm *et al.*, 1981; Thurman, 1985). These findings indicate that particulate carbon is mobilized to a greater degree from watersheds than dissolved carbon during periods of high rainfall, such as the summer monsoon season in Korea.

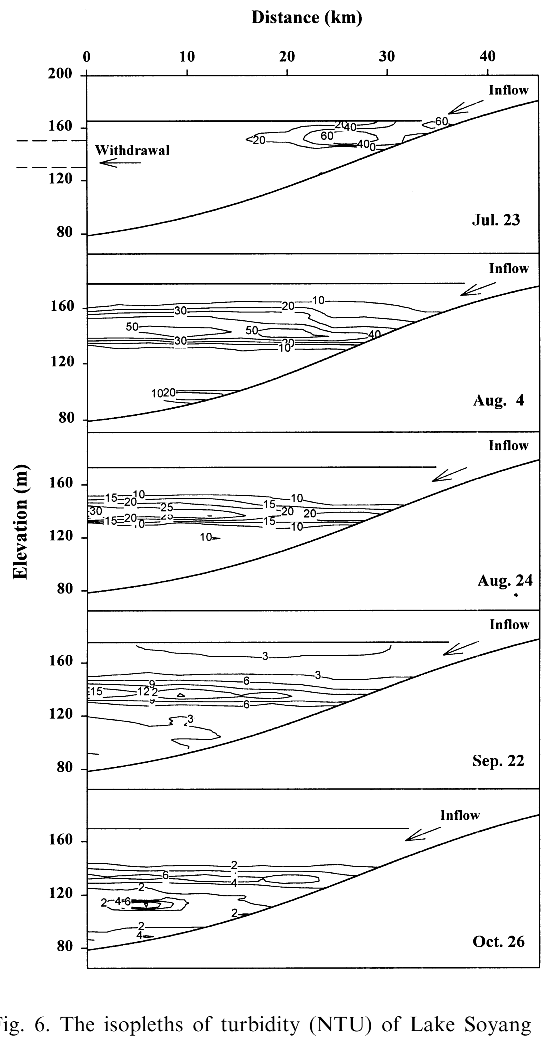

Fig. 6. The isopleths of turbidity (NTU) of Lake Soyang showing inflow of higher turbid water into the middle layer after heavy rainfall, from July to October 1996.

Because there are few natural lakes in Korea, reservoirs and rivers are the predominant form of freshwater ecosystem. In natural lakes, inflows usually are restricted to overland flow and small streams, and their impact is confined to the littoral zone and surface waters (Ford, 1990). In contrast, in reservoirs such as Lake Soyang, located at the upstream part of a river in mountainous terrain, inflows usually enter at the upper end of the reservoir. There is little or no interaction with littoral zones, and the inflowing water enters the reservoir along the layer of constant density. In Lake Soyang, storm runoff water flows into the middle layer of the lake during the summer monsoon season because the density of inflow water is usually greater than that of the surface water (Fig. 6). In addition, one half of annual precipitation in Korea is concentrated in several heavy showers during the summer monsoon season in July and August. Therefore, the summer monsoon has a dramatic impact on Lake Soyang, its river inflow, and other river-reservoir systems in the region.

Plankton is largely flushed from a reservoir during the monsoon season if residence time is short and/or depth is shallow. However, this is not the case in deeper reservoirs with longer residence times such as Lake Soyang. During the summer monsoon season turbid flood runoff is stored in the middle of the reservoir, resulting in high DOC and POC concentrations in the middle layer. However, this turbid water is soon discharged from the dam via the outlet located at the middle depth (elevation 130–150 m) (Fig. 6). Only a part of the turbid water remains in the lake until September. Kim *et al.* (1995) reported that cyanobacterial blooms occur about a month after the summer monsoon every year. They suggested that nutrients remaining in the turbid middle layer are supplied to the upper layer with sinking of the thermocline in late summer, and that this stimulates cyanobacterial blooms. Some nutrients also may be supplied to the epilimnion in the monsoon season directly from the shoreline and adjacent watershed.

The ratio of DOC:POC in Lake Soyang was similar to that observed in low productivity lakes, but the ratio varied largely according to season and depth. The ratio mainly depended on changes in POC concentration, because variability of POC was larger than DOC. Seki and Nakano (1981) reported that phytoplankton was a major component of POC in lakes. In Lake Soyang, the decreased DOC:POC ratio in the upper layer may have been due to phytoplankton, whereas in the middle layer the decreased ratio was more likely caused by the turbid water inflow.

From the positive linear relationship between POC and chlorophyll *a* in the euphotic zone of Lake Soyang, it is suggested that phytoplankton were a significant component of POC during the summer. Particulate detrital carbon, estimated from the Y-intercept of the least-squares regression model, contributed only 196 $\mu g\ l^{-1}$ and 333 $\mu g\ l^{-1}$ in 1995 and 1996, respectively to the total POC. Descy and Gosselain (1994) reported that the mean percentage of phytoplankton carbon was 56.8% (range 12.5–92%) of total POC in a large lowland river, the Meuse River in Belgium. In Lake Soyang, the autumn and winter POC profiles were quite uniform at low levels, and phytoplankton biomass also was reduced. At this time, the turbid water of the middle layer had been washed out through the dam.

DOC can be released during photosynthesis by living algae (Mague *et al*., 1980; Jørgensen, 1986; Søndergaard *et al*., 1985) and dead algae (Hansen *et al*., 1986). Hama & Handa (1983) and Fukushima *et al*. (1996) reported that DOC concentration was high during and after algal blooms in a Japanese lake. The chemical composition and amount of DOC released depends both on the physiological state of the algae (Nalewajko and Lean, 1972) and the algal species (Chrost and Faust, 1980). Søndergaard *et al*. (1985) found that the released DOC ranged from 5 to 46% of total primary production in a European lake. Hwang (1995) reported that 9–67% of the primary production was released as DOC in Lake Erie, USA. Therefore in Lake Soyang, the high DOC concentrations during cyanobacterial blooms may have been due to DOC excretion by phytoplankton. After the blooms, a lack of relationship between chlorophyll *a* and DOC concentrations may have been due to leachate from dead phytoplankton.

High DOC near the lake bottom in Lake Soyang may have been due to release of organic matter by heterotrophic organisms in the sediment. An anoxic bottom layer has occurred in the lake since 1988, reflecting cultural eutrophication. The anoxic layer has been associated with high concentrations of phosphate and ammonia, and depletion of nitrate (Kim and Cho, 1989). Those results, along with the higher DOC concentration near the bottom, imply that many organic particles are settled and degraded at the bottom of the lake.

DOC concentration in lakes generally increases with eutrophication. Typical concentrations of DOC in oligotrophic, mesotrophic, and eutrophic lakes range between 1 and 3, 2 and 4, and 3 and 34 mg l^{-1}, respectively (Thurman, 1985). In Japanese lakes, DOC concentrations of 3.4 and 4.4 mg l^{-1} were measured in eutrophic Lakes Suwa and Nakanuma. Concentrations of 2.2 and 0.9 mg l^{-1} were measured in mesotrophic Lake Kizaki and oligotrophic Lake Aoki, respectively (Ochiai and Hanya, 1980; Hama and Handa, 1980). In Lake Soyang, low concentration of DOC in the dry season is typical of oligotrophy and higher DOC in the summer and early autumn is typical of mesotrophy according to the classification scheme of Thurman (1985).

In this study, total loading of allochthonous organic carbon was concentrated during several heavy rainfall events during the summer monsoon season. The loading of organic carbon to a reservoir lakes from its watershed varies with climate, vegetation, and the season of year (Thurman, 1985), and the loading from allochthonous sources generally is higher than in natural lakes because of the larger drainage basins and greater water level fluctuations (Wetzel, 1990). Brinson (1976) reported that annual TOC loading from the watershed was directly proportional to the annual runoff. In Lake Soyang, the summer monsoon rains may be the most important factor contributing the allochthonous organic carbon loading. The loading of organic carbon from allochthonous sources affected the distribution of organic carbon in Lake Soyang, but most of the allochthonous matter is discharged from the lake without affecting the upper layer. Therefore, although the loading of allochthonous organic carbon was as large as the autochthonous generation, the autochthonous matter is thought to be the major energy source for secondary producers in this ecosystem.

CONCLUSIONS

Summer monsoon rains were an important factor controlling the distribution of organic carbon in Lake Soyang, Korea. Turbid storm runoff supplied organic carbon to the middle layer of the lake during the monsoon. In the upper layer, there was a high rate of autochthonous carbon production by phytoplankton after the monsoon ended. Most of the allochthonous carbon loading was concentrated during heavy rainfall events in the summer, and total allochthonous loading was as large as autochthonous generation. However, autochthonous organic matter appears to be a more important energy source for secondary producers because most of the allochthonous carbon is discharged by the dam without affecting the upper water layer. There was a significant relationship between POC concentration and chlorophyll *a*, but DOC and chlorophyll *a* were unrelated. Further research is needed to quantify the role of DOC excretion from living algal cells and loss from dead cells in this and other deep reservoir lakes. The results of this study indicate a number of unusual features of deep reservoir lakes, in regard to their organic carbon budgets, and this information may help in the development of general models of carbon dynamics for these ecosystems.

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