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Distribution of Particulate Organic Matter in the Kum River, Korea

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INTRODUCTION

Particulate organic matter (POM) in freshwater ecosystems is an important organic substance, and serves as a primary energy source for the functioning of the entire food chain in the designated riverine system [13, 17 18, 19]. In spite of this importance of POM in terms of elemental base in particulate organic carbon (POC) and nitrogen (PON), its distribution and the role of tropho-dynamics in the freshwater ecosystem is poorly known particularly in Asian environment. For Korea, and man-made lakes in particular, the distribution and the characteristics of suspended particulate matter (SPM) have been reported only by very few researchers [4]. The report of Choi *et al.* (1985, [4]) emphasized the ecological importance of this matter in freshwater reservoirs, in particular with reference to a newly formed lake in an estuary after the building of a river barrier, ie., Yongsan Lake, Korea.

Park *et al.* (1992, [12]) reported that Daechung Reservoir Lake is in the stage of ever increasing stress of eutrophication and the consequent algal bloom has become evident and common in summer. We report here the distribution of SPM, POM, POC, PON and some environmental parameters; temperature, pH, DO, BOD, nutrients (NO3 and PO4), chlorophyll *a* and DNA contents at five distinctively different sites along the Kum River system during April, July, August and September of 1993 to determine its characteristics and to discuss the importance of this matter in one of the major rivers of Korea, the Kum River.

MATERIALS AND METHODS

The samples analyzed in this study were collected four times in 19 April, 27 July, 20 August and 22 September 1993 at five stations on the Kum River, Korea (Fig. 1). The Kum River is 401 km long and has a catchment area of 4,184 km^2 ; it is one of the four major rivers of South Korea, flowing through the mid-lands of the Korean Peninsula to the Yellow Sea [7]. The Daechung Dam was constructed in 1980 for an artificial freshwater supply, and the resulting Daechung Reservoir

Lake has a surface area of 72.8 km^2. The dam site is located 150 km from the Kum River Estuary [8].

Stas. 1 and 2 are located on the Daechung Reservoir Lake. Sta. 1 is the deepest and just beside the dam. Sta. 2 is also on the edge of the lake at a distance of 9 km from the dam site. Sta. 3 is in the immediate vicinity of the outfall of the dam. Sta. 4 is 36.4 km downstream from the dam and is near the outskirts of the city of Kongju. Sta. 5 is very shallow (usually less than a meter in depth) and located 12 km downstream from the dam in confluence area of two streams - the Daejonchon and Eudongchon - which are heavy loaded with domestic and industrial effluents [9, 10].

The collection sites are among those routinely studied over the past two years by Lee *et al.* (1993,[9]; 1994,[10]) and currently under study by Choi (1992,[3]).

Sampling routines were all similar. Water samples were taken in standard PVC 3L Van Dorn bottles and were collected from the surface and the bottom. Vertical profiles of up to six samples cover the entire water column for Sta. 1. Because of its shallowness only surface samples were collected at Sta.5.

The water temperature, salinity, conductivity, turbidity and dissolved oxygen (DO) were measured electrometrically in the field using in situ probes (Horiba, U-10). Duplicate samples for DO were later re-checked by the Standard Winkler Method (1985,[1]). Field pH determinations were made immediately after the water was brought to the surface with a battery operated digital *p*H meter (SP-2200, Suntex Inst.). The biological oxygen demand (BOD) was determined by volumetric titration followed by the ALPHA method (1985,[1]. The nitrate and phosphate contents were analyzed by potenciometric titration using a spectrophotometer.

The 90% acetone extracted chlorophyll *a* were measured spectrophotometrically following Strickland *et al.*, (1972,[5]). The DNA content was measured by the spectro-fluorometric method using aromatic fluoroscent dye DAPI [16].

Pre-weighted glass fiber filters (Whatman GF/F) were used for the analysis. The SPM retained in the filter was combusted in an electric muffle furnace at 500 ℃ for an hour, and the weight difference after conbustion (ignition loss) was considered as POM. For POC and PON, the volume of measured water samples were filtered through glass fiber filters (Whatman GF/F) prebaked in an electric muffle furnace. After rinsing with filtered distilled water and briefly treated with 1N HCl, these filters were later analyzed for the concentration of POC and PON by the gas-chormatographic method using an Elemental Analyzer (Perkin Elmer CHN Analyzer 240-B). Sample filtration, treatment and preparations were base on the methods of Gordon (1969,[5]; 1970,[6]), Strickland and Parsons (1972,[15]), Choi (1982,[2]), and Choi *et al.* (1985,[4]) with slight modification.

RESULTS AND DISCUSSION

Data plotted in Fig. 2 show the vertical profiles of temperature, pH, nitrate, phosphate, DO, chlorophyll *a*, DNA and total chlorophyll concentrations at Sta.1.

During the survey, the minimum temperature recorded 6.5 ℃ at 20 m in April and the maximum of 26 ℃ was recorded at the surface in August 1993. The vertical profile of temperatures shows slight thermocline development at 10 m in April and 30 m in September; the water body above this depth was homogeneous. The lower temperature average of 13.6 ℃ in April and the higher average (22.7 ℃) for August appeared as expected. The *p*H ranged 6.84~9.82 with an average of 7.88. Relatively higher *p*H appeared in the epilimnion.

The results of environmental variables during the survey are shown in Fig. 3. In general, DO concentrations of Stas. 1 and 2 were higher than those of Stas. 4 and 5. The DO ranged from 1.26 to 11.33 mg/*l* and the average DO of April (9.24 mg/*l*) and of July (7.55 mg/*l*) was higher than those of August (5.54 mg/*l*) and September (4.97 mg/*l*).

The BOD showed wide variation and ranged from 0.4 to 12.20 mg/*l* with an average of 4.17 mg/*l*. The average of BOD content was highest in July (6.18 mg/*l*), compared with 4.24 in April; 3.78 in August and 2.80 mg/*l* in September. Among the highest BOD readings was that for July at Sta. 1 (surface) of up to 14.85 mg/*l*. This was thought due to the excessive accumulation of litter at the dam site including fallen and degraded leaves, other vegetation debris, organic matter after previous heavy rain fall and some by phytoplankton growth as indicated by the chlorophyll contents.

Sta. 5 showed consistently high BOD content with an average of 10.43 mg/*l*; average BOD was 3.41 for Sta. 1; 4.22 for Sta. 2; 1.47 for Sta. 3 and 4.45 mg/*l* for Sta. 4. In terms of BOD content, Daechung Reservoir Lake is becoming overloaded with higher organic matter [8].

During the survey period nitrate concentration ranged from 0.78 to 6.79 μM with an average of 2.33 μM, and the phosphate ranged from 0.14 to 16.80 μM with an average of 6.55 μM. In general, phosphate contents were higher than those of nitrate. Temporal variation of nitrate showed high in April (3.01 μM) and low in September (1.32 μM); conversely phosphate appeared low in April (2.17 μM) and high in September (10.77 μM). Both nutrients appeared low in Stas. 1 and 2, and increased downstream (Fig. 3). The vertical profile of these nutrients at Sta. 1 showed less nitrate variation except for the surface high in August, yet the phosphate concentration showed considerable vertical variations. In comparison with nitrate, the absolute amount was also higher.

Through the survey period the SPM amount ranged from 11.20 to 44.07 mg/*l* with an average of 22.39 mg/*l*. The results also indicated that the distribution was highly variable. The highest monthly average appeared in July (26.85 mg/*l*) with lower values in August (19.11 mg/*l*) and September (20.53 mg/*l*). Highest SPM concentration (44.07 mg/*l*) occurred in July at Sta. 4 (surface) where the water had become shallow and resuspension of the sediments prevailed.

The amount of POM considered as ignition loss of the collected SPM ranged from 0.63 to 12.19 mg/*l*. The percentage of POM to SPM averaged 11.8%.

However, the vertical profile of the ignition loss to SPM at Sta. 1 showed a more variable pattern: 33.9% at the surface and 2.0% at 35 m in April 1993. Current results are in good agreement with the average organic matter content of river particulate matter lies between 1~5%, ranging from less than 0.5 to more than 20% [11].

The station averages of POM for April, August and September were 2.87, 2.22, and 1.02 mg/*l* respectively, showing a relatively stable distributional trend. In July, however, average POM was 4.27 mg/*l* and this was 15.4% of SPM. This higher POM content in July was more evident in Stas. 1 (5.06 mg/*l*) and 2 (4.52 mg/*l*). We found surface bloom of *Anabaena* sp. at this time. High chlorophyll *a*, total chlorophyll concentrations and DNA data (Fig. 2) all support this increased amount of POM.

Kim *et al.* (1984,[8]) and Park *et al.* (1992,[12]) revealed that Daechung Reservoir Lake in the summer phytoplankton succession is predominated by *Anabaena, Anacystis* and *Microcystis* sp., and that the bloom is usually one of these species.

The surface bloom of *Anabaena* sp. in July has been coincided with high contents of chlorophyll *a* (5.02 μ g/*l*), total chlorophyll concentrations (8.08 μ g/*l*) and DNA (16.27 μ g/*l*). At Sta. 1 the correlation between POM and chlorophyll *a* was highly significant ($P<0.01$) as was shown in the same highly significant relationship between chlorophyll *a* and POM in North Sea [14]. This relationship does not necessarily mean that higher POM content on the surface is contributed by primary production. However, it appears that increased amounts of POM cam be autochthonous in origin. At Sta. 4 surface, high SPM (44.07 mg/*l*) did not yield high POM (4.48 μ g/*l*) and POM was only 10.2% of SPM. Here the biomass data were not significantly correlated with POM either ($P>0.05$).

Spatial variability of the station average in POC ranged from 401.2 to 5,145.3 μ g/*l*, and this was averaged 65.5% of the POM. The PON station average ranged from 10.4 to 1,130.4 μ g/*l*, with an average of 229.1 μ g/*l*, and was 9.1% of POM respectively. Temporally both POC and PON appeared highest in July and lowest in September.

The C/N ratio ranged widely from 3.0 to 38.6 and averaged 8.2. The C/N ratio appeared highest in April (10.4) and lowest in September (5.9). The average C/N ratio was higher in Stas. 1 and 2, decreasing downstream towards Stas. 3, 4 and 5. Sta. 5 showed constant low values of C/N ratio, and this is thought to be due to the large amount of sewage effluent high in nitrogenous materials entering the Kum River system from the city of Daejon [9].

Following Table 1 is a comparison of the POM data with those of Lake Youngsan, July, 1984. Lake Yongsan is a reservoir lake formed by a building of river barrier in the Yongsan Estuary, Korea.

The two man-made lakes are distinctly different with respect to the distribution of POM. In Lake Yongsan, the SPM amount including ignition loss and residue are absolutely higher, yet POC and PON are less than those of Daechung Reservoir Lake. The C/N ratio is also higher in Daechung Reservoir Lake. Furthermore, estimated phytoplankton carbon from the chlorophyll data and the percentage of this carbon to POM is also higher (x 2.2) in Daechung Reservoir Lake.

In terms of general trends and the distribution of POM together with the subsequent elemental basis of POC and PON from the current data, it is reasonable to assume that Stas. 1 and 2 of Daechung Reservoir Lake are affected by autochthonously originated organic matter input, and Stas. 4 and 5 are mostly affected by other allochthonously originating organic matter to the system including domestic, industrial and agricultural discharge from surrounding areas. The POM contents of Sta. 3 is somewhat intermediate between that Reservoir Lake Stas. 1 and 2 and lower stream Stas. 4 and 5.

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Table 1. A comparison of SPM, Ignition loss(IL), Residue(R), POC, PON and C/N ratio in Lake Yongsan, July, 1984* and Daechung Reservior Lake in July, 1993.

Lake	SPM(a) (mg/l)	IL(b) (mg/l)	R (mg/l)	b/a (%)	POC(c) (mg/l)	c/b (%)	PON(d) (mg/l)	d/b (%)	C/N	Remarks
Yongsan	49.2	11.9	37.2	24.2	1.39	11.7	0.25	2.1	5.6	4 Stas.Average; July, 1984
Daechung	28.8	4.8	24.5	16.5	3.34	69.0	0.46	9.0	8.3	2 Stas.Average; July, 1993

* Choi and Chung(1985,[4])

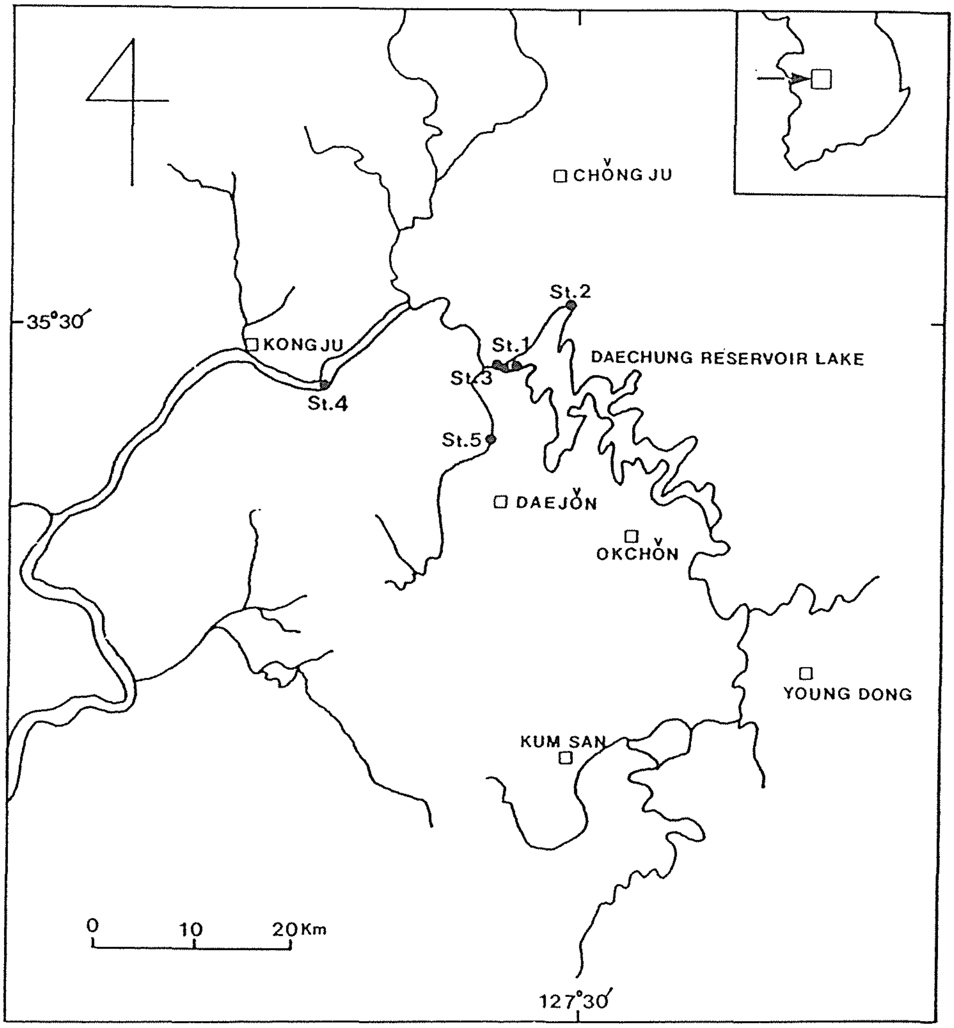

Fig. 1. Map of sampling stations in Kum River area.

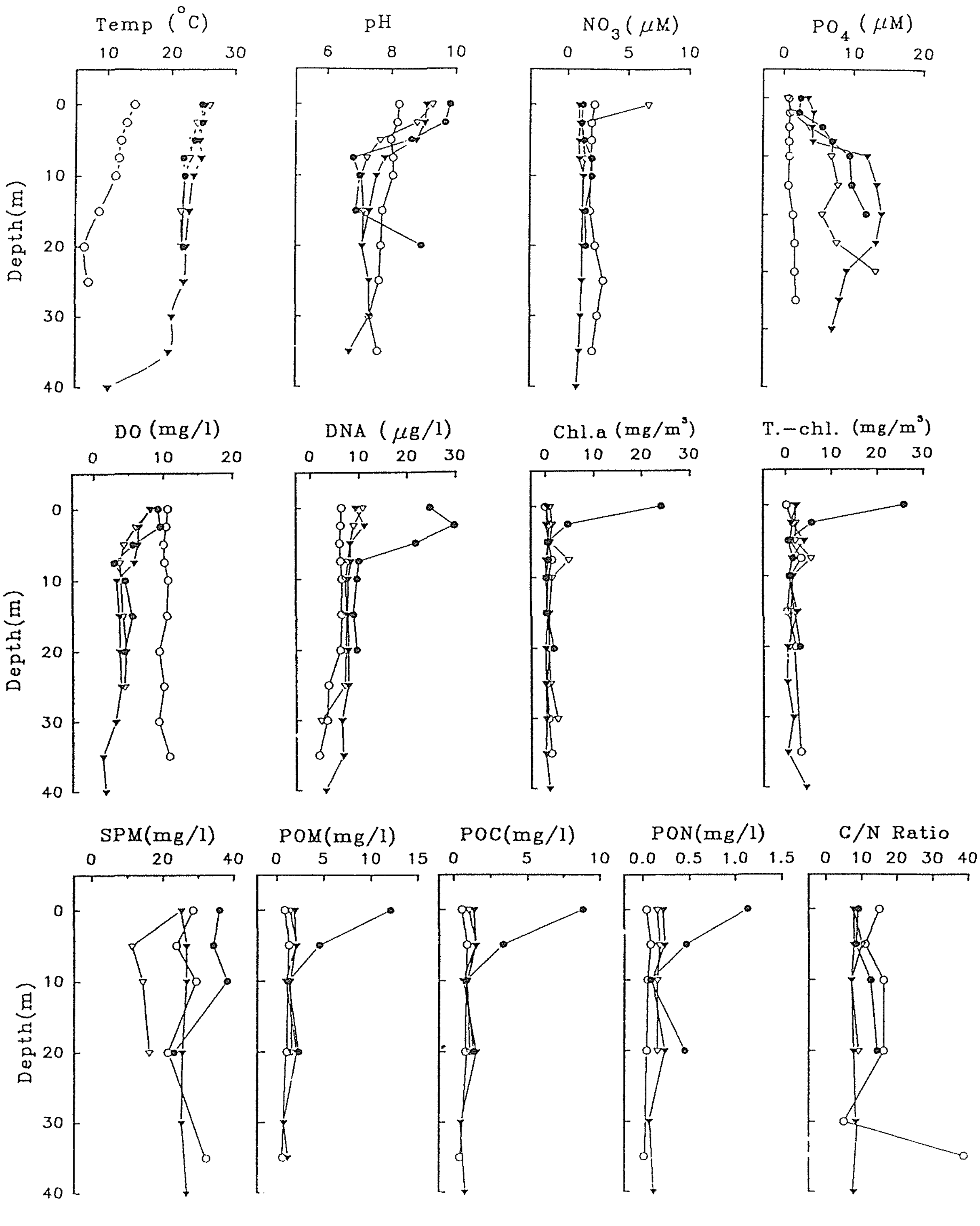

Fig. 2. Vertical distribution of environmental variables and particulate organic matter during April(○), July(●), August(▽) and September(▼), 1993 at Sta. 1 of Daechung Reservoir Lake, Korea.

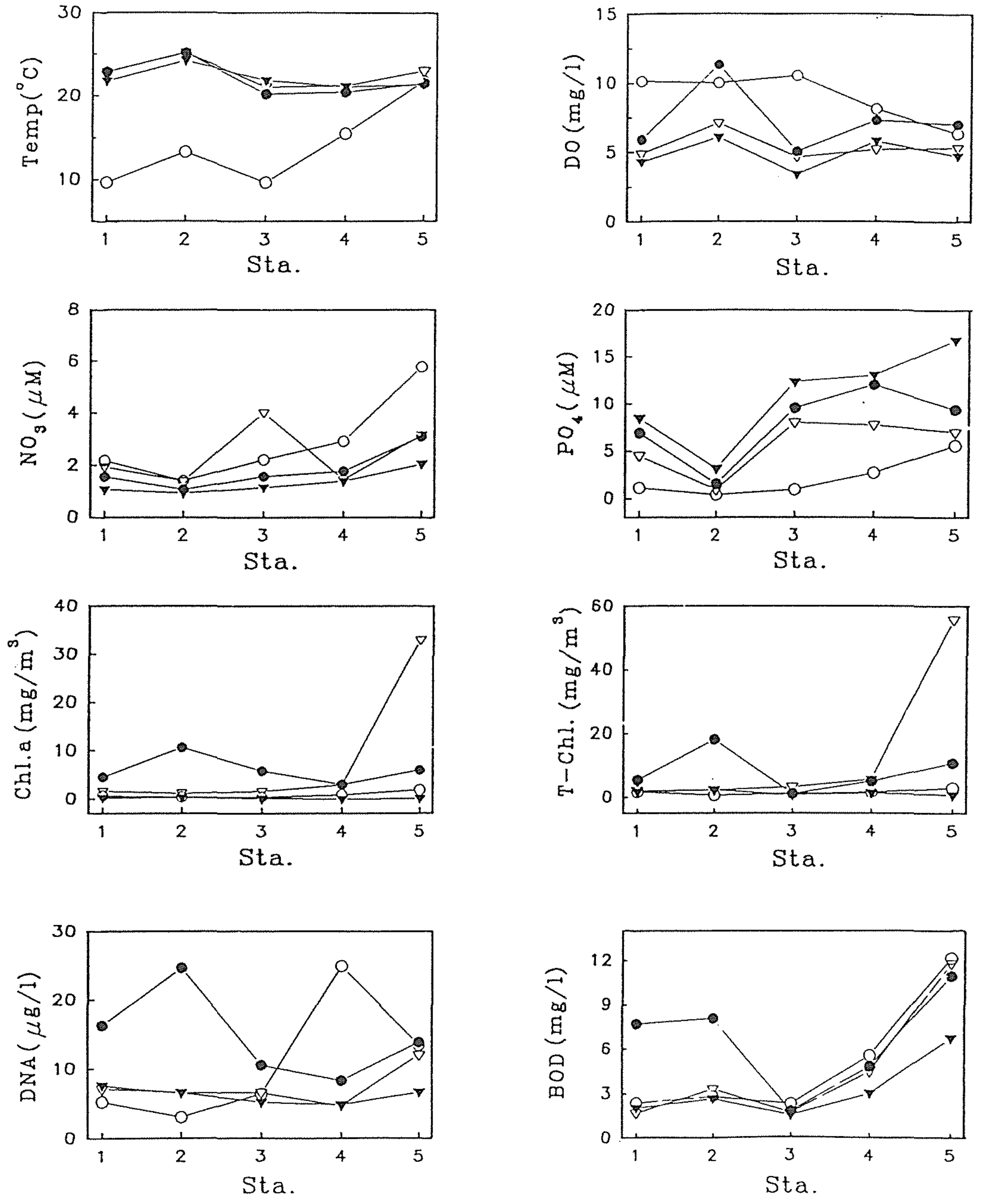

Fig. 3. Spatial distribution of the mean environmental variables during April(○), July(●), August(▽) and September(▼), 1993 in Kum River, Korea.

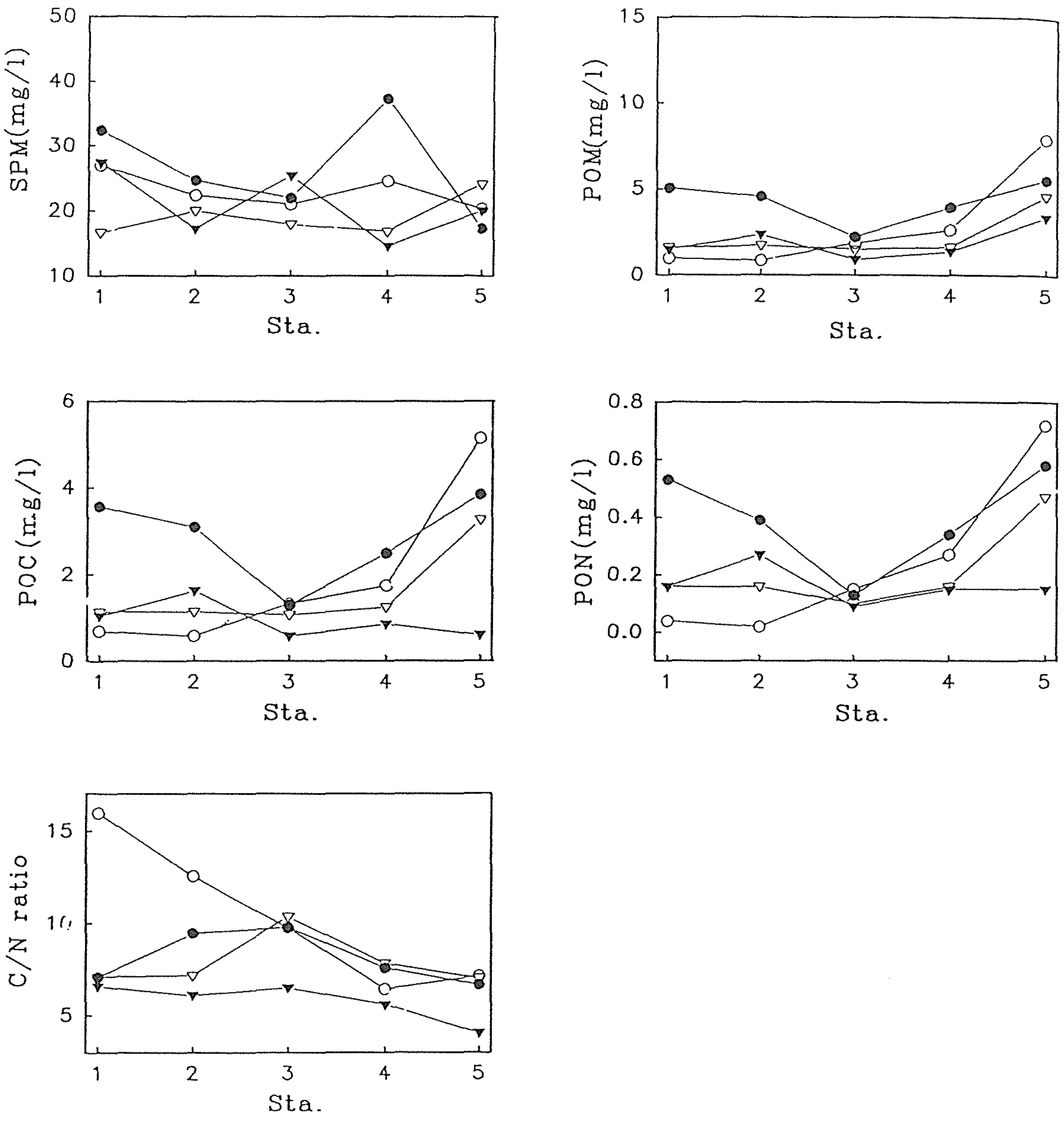

Fig. 4. Spatial distribution of the mean SPM, POM, POC, and C/N ratio during April(○), July(●), August(▽) and September(▼), 1993 in Kum River, Korea.