PERIODICITY OF PHYTOPLANKTON IN A WATER RESERVOIR IN NORTHERN TAIWAN

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Abstract: The characteristic periodical changes in the species and communities of phytoplankton in a pond situated in northern Taiwan were studied for three years, from July 1986 to June 1989. The physico-chemical factors as well as the amount of zooplankton were taken into account to elucidate the relation of them to the variations in phytoplankton assemblages. The results show that the steady increase in phytoplankton density during the study time is not due to the decline in grazing pressure. The maximum of phytoplankton densities in the pond was developed toward summer. Nevertheless, seasonal succession in phytoplankton communities was not evident. The results from the analysis of water quality and from the indicator species of phytoplankton indicate that this pond was in hypereutrophic state and of the level between beta- and alpha-mesosaprobity. High nutrient concentration in the pond and mild temperature in winter were regarded to be the main reason resulting in the irregularity of the periodical changes in phytoplankton assemblages.

INTRODUCTION

It is a well known phenomenon that phytoplankton show a periodical change in quantitative as well as in qualitative characteristics in response to seasonal cycle. The type of change is various in different geographical zone and in different aquatic environments of the same area. The characteristics of the seasonality of freshwater phytoplankton in different geographical zones had been well revised by Munawar and Talling (1986).

The seasonality of phytoplankton is conditioned by that of climate. In the past, the majority of studies were conducted in north-temperate zone. Taiwan is an island situated in north-subtropical zone. Few information about the seasonality of freshwater phytoplankton was known in this island. Shen (1961) had reported phytoplankton populations and their seasonal succession in some fishponds of a southern area of Taiwan. Little more about the ecological characteristics of phytoplankton has been studied in this island. In order to get better knowledge about the phytoplankton in aquatic ecosystem, a study for a period of three years was conducted in a pond which serves as water reservoir for rice field and, in the meanwhile, as a pond for fish culture.

MATERIAL AND METHODS

Phytoplankton samples in a pond (denoted as KD) situated at Hsintzu, Taiwan

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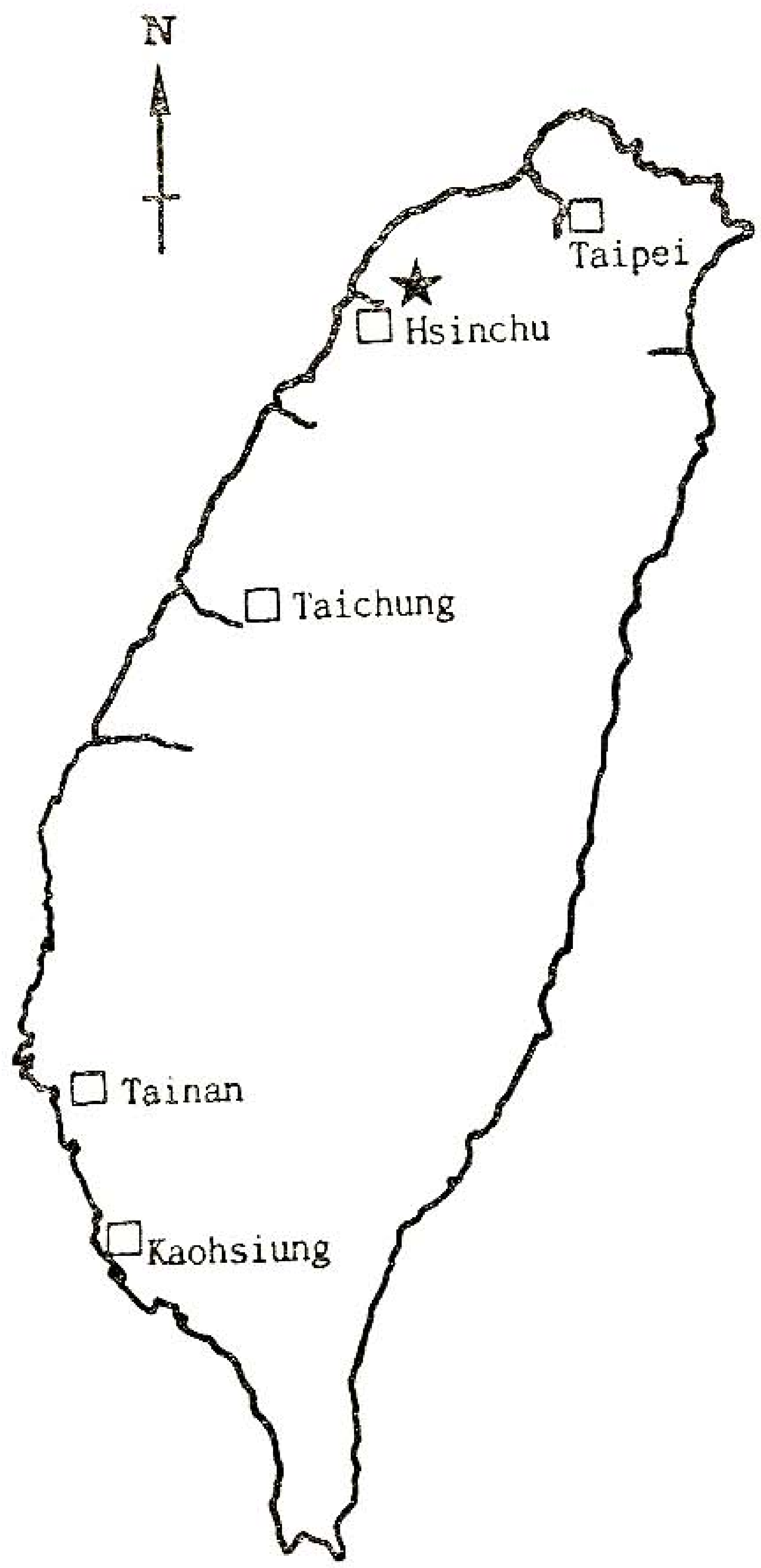

Fig. 1. Map of Taiwan, showing the sampling locality (★).

(Fig. 1) were collected once a month from July 1986 to June 1989. Samples were fixed with Lugol solution and dehydrated by gradual replacement of water with glycerol. The dehydrated samples were mounted on slides for microscopic observation.

The samples for quantitative determination of phytoplankton density was prepared by filtering the samples through a membrane filter (pore size 0.45 μm). The counting of cell number was conducted after membranes had become transparant in immersion oil (Merck 4699). The frequencies of the presence of each species were calculated on the basis of at least one thousand counts for a sample. The diversity of phytoplankton community was estimated by Shannon index (Shannon and Weaver, 1949).

Zooplankton samples were collected by a plankton net (55 μm) from three liters of pond water. They were counted under microscope.

The quality of pond water was physico-chemically analysed by the Tzupei Fisheries Research Institute. The parameters such as water temperature, transparancy, dissolved oxygen, redox potential, biochemical oxygen demand as well as the concentrations of nitrate, nitrite, ammonium, total phosphate and alkality were adopted from standard methods (Greenberg *et al.* 1985). To avoid the influence of daytime on the analysis of water quality, the measurement of water quality was conducted round at noon.

RESULTS

Physico-chemical environment of the pond

Kd pond has a surface area of 7.8 ha, mean depth of 4.5 m. It serves as water reservoir for rice field. The depth of water was kept always more than 2 m. *Tilapia* sp. was the main fish species grown in this pond.

The seasonal fluctuation of water temperature was evident during the time of study. Fig. 2 shows that the highest temperature was in July, about 32°C, and the lowest in February, about 12°C. Other physical parameters such as Secchi disk transparency, dissolved oxygen (DO), biochemical oxygen demand (BOD_5), and redox potential also fluctuated to some extent throughout the study time. However, they did neither match with that of temperature, nor with each other.

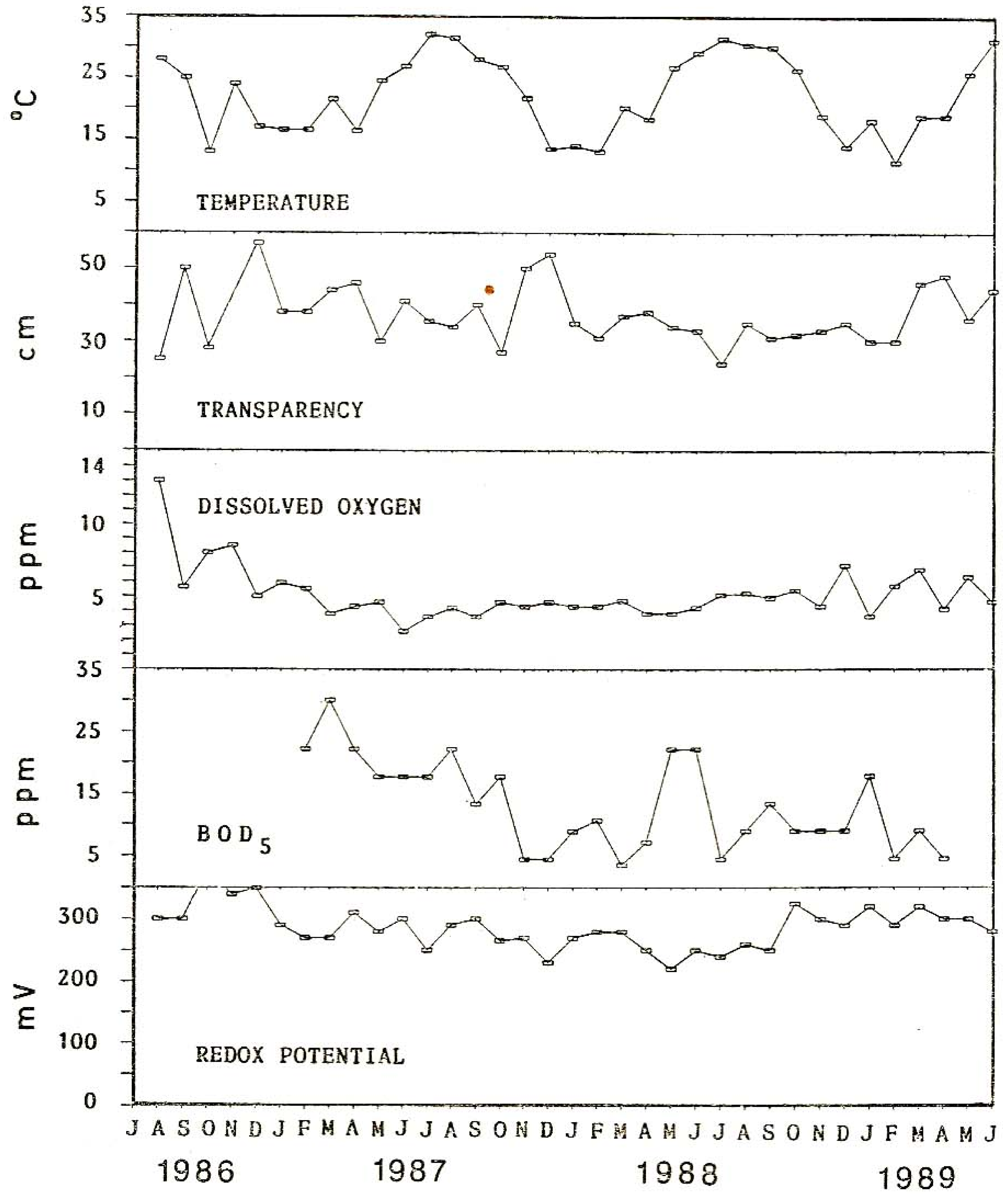

Fig. 2. Physico-chemical parameters in the KD pond, showing the fluctuation of them during the time of study.

Low Secchi disk transparancy, ranging between 25 and 57 cm, and high chlorophyll content, always higher than 12 mg/l, showed that this pond was always in eutrophic state.

The DO in the pond generally fluctuated within a day. The values measured at noon showed that DO was relatively little changed during the time of study, mostly varied between 4 and 7 mg/l. The change in DO content in water showed an independency of seasonal change.

The BOD_5 of water was usually higher than 5 mg/l. It had been as high as 20 mg/l in several months. This indicates that the water quality of this pond could be either of alpha-meso- or of polysaprobic state.

High redox potentials, usually higher than 250 mV, also implicates that this pond was in moderately polluted state.

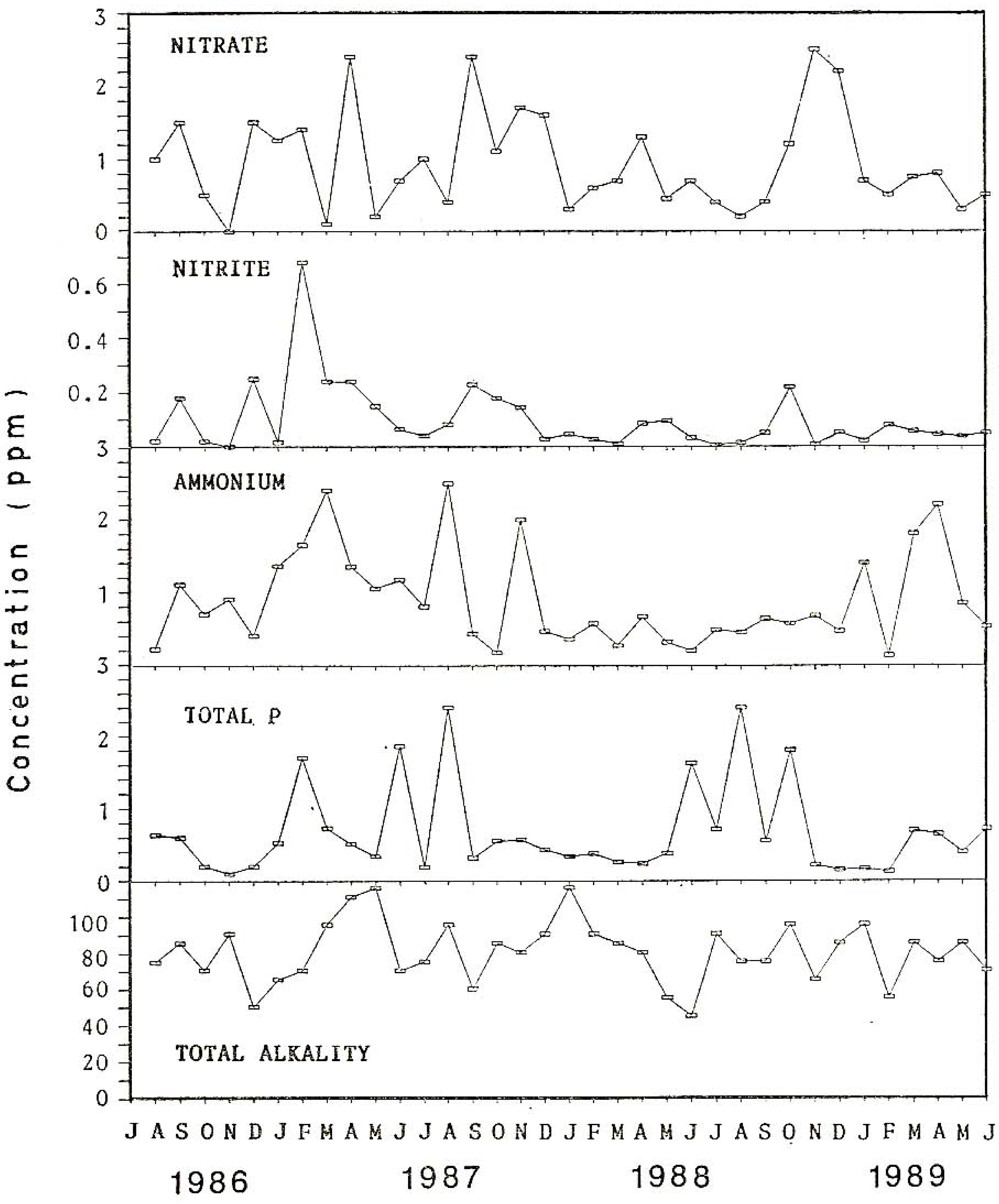

Fig. 3. Some chemical parameters in the KD pond, showing the fluctuation of them during the time of study.

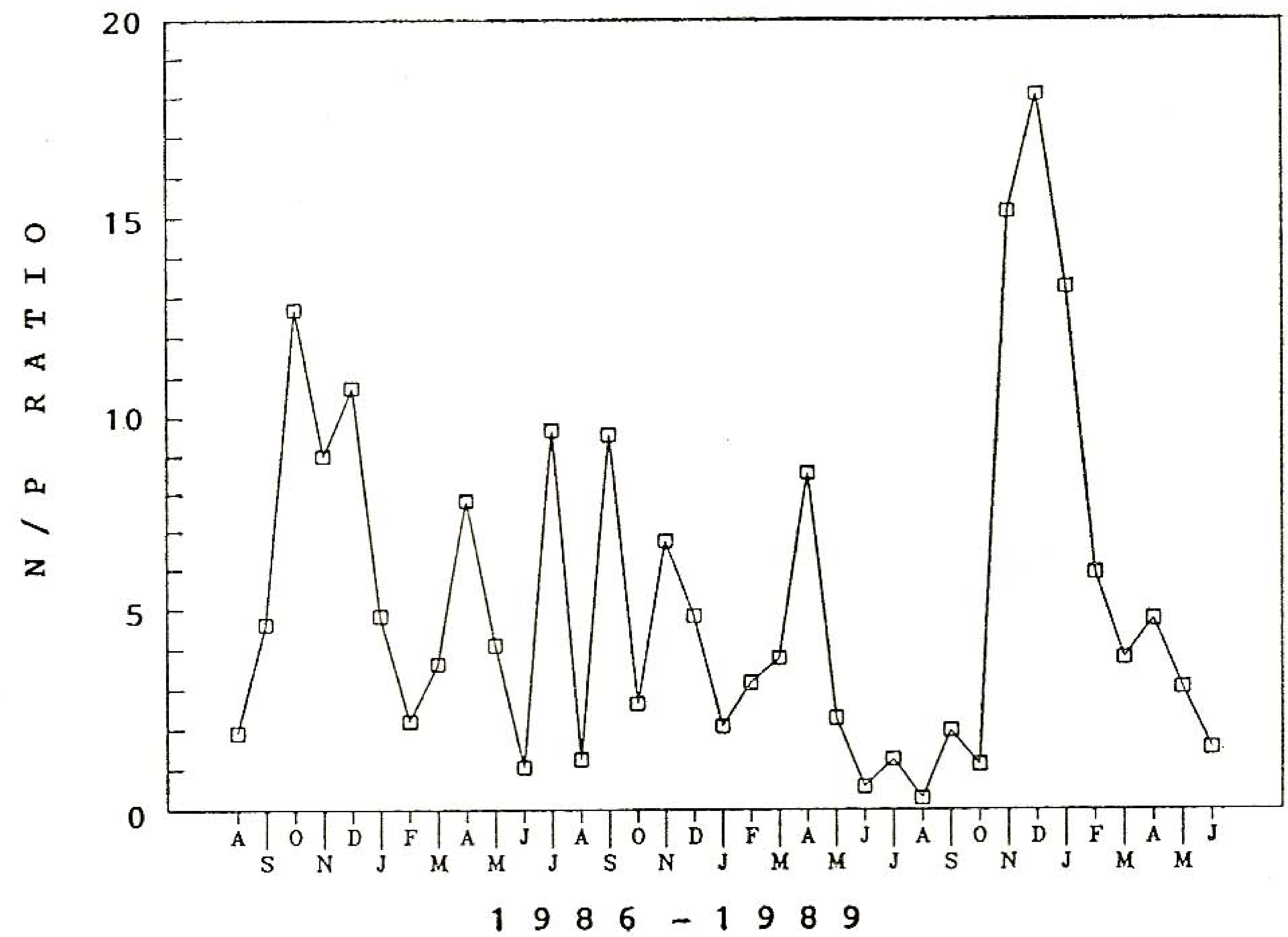

Fig. 4. Fluctuation of N/P ratios in the KD pond during the time of study. N was the sum of inorganic N; P was soluble inorganic P.

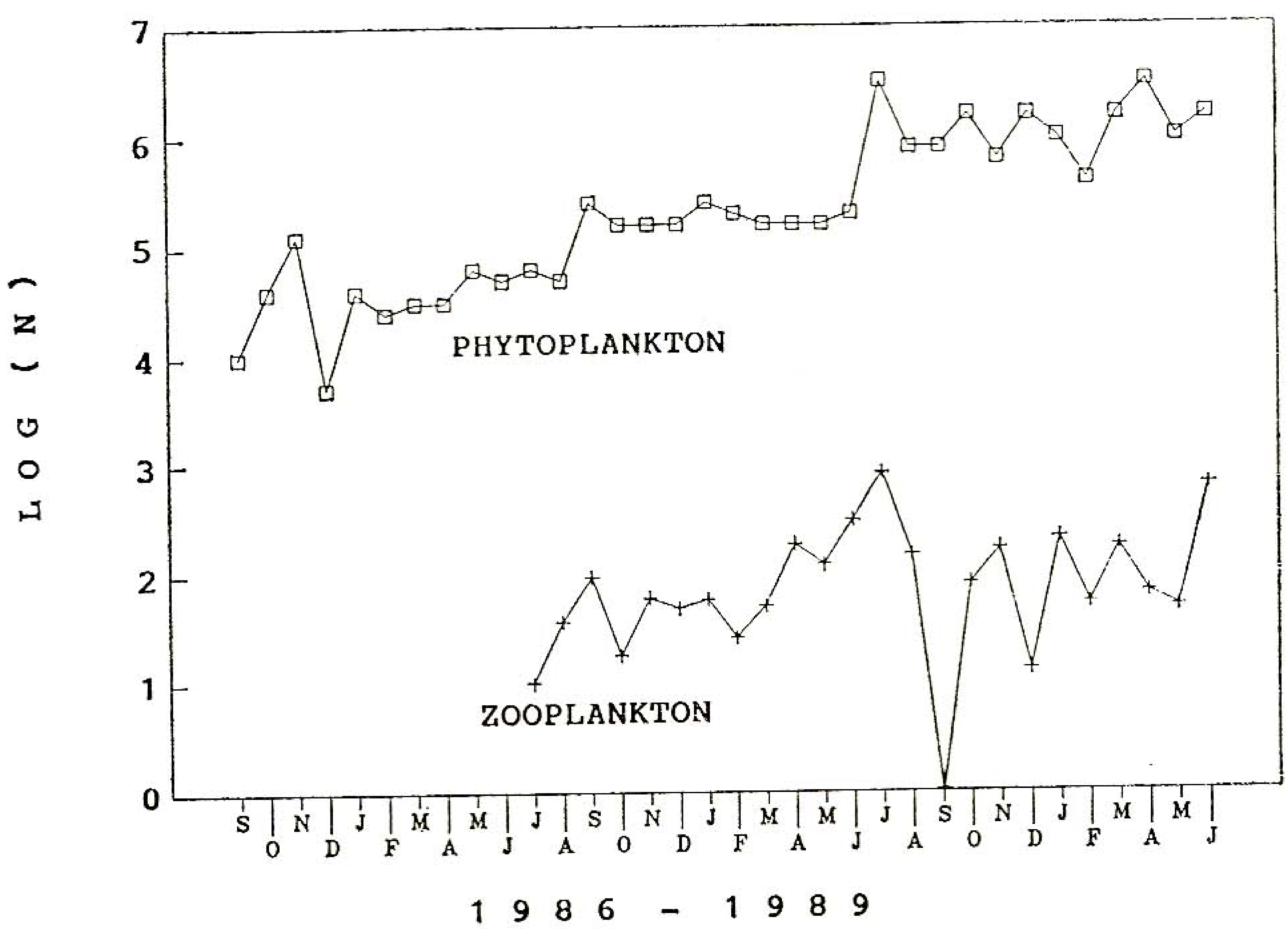

Fig. 5. Change in the densities of phyto- and zooplankton in the KD pond during the time of study. Cell density (N) for phytoplankton: cells/ml, for zooplankton: individual/l.

This pond had rather high nitrite and ammonium contents (Fig. 3). The content of nitrite fluctuated, approximately parallel to the variation of nitrate content. In contrast, the change in the content of ammonium did not show any correlation with that of nitrate, nitrite or total alkality.

The content of total phosphorus (TP) in the pond fluctuated periodically. In general, TP was relatively high in summer. This gave rise to a lower N/P ratio during that time (Fig. 4). Low TP content in the winter of 1988 gave rise to the extraordinary high N/P ratio at that time.

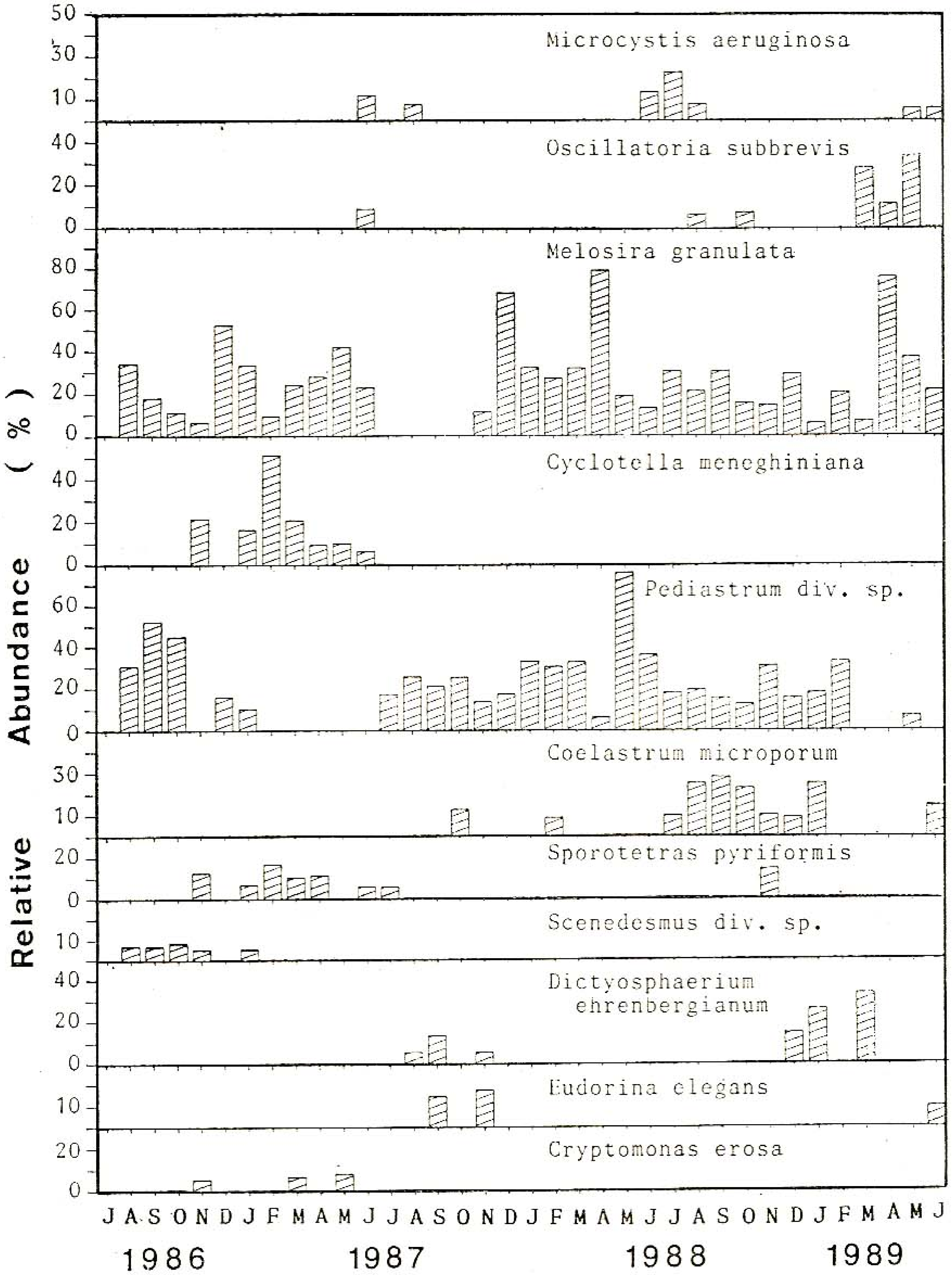

Fig. 6. Seasonal occurrence, degree of dominance (% abundance) of eleven most important species of phytoplankton in the KD pond during the time of study.

Quantitative characteristics of plankton in the pond

The density of phytoplankton in the pond was rather high, ranging from 5.0×10^3 to 5.0×10^6 cells per ml. An increase in density from year to year was observed (Fig. 5). During the study time, seasonal fluctuation in phytoplankton density was not very evident, except that there was a pronounced increase in density in summer, namely in September 1987 and July 1988.

The study of zooplankton in this pond began since July 1987. The density of zooplankton ranged from 11 to 812 individuals/l. In general, the number of zooplankton increased when the density of phytoplankton increased. The average ratio of the density of phytoplankton to that of zooplankton was about 1.1×10^7:1.

Qualitative characteristics of phytoplankton in the pond

Chlorophyte was the most important component of phytoplankton assemblage in the pond. It contributed the main biomass not only in spring and autumn, but also in summer (Fig. 6). Numerous green algal species appeared in the pond throughout the time of study. Among them, the dominant species were *Pediastrum* div. sp., *Coelastrum microsporum, Sporotetras pyriformis, Dictyosphaerium ehrenbergianum Monoraphidium tortile, Oocystis lacustris, Scenedesmus* div. sp. and *Eudorina elegans* (Fig. 7).

Diatoms were subdominant group in this pond. It dominated, as in many

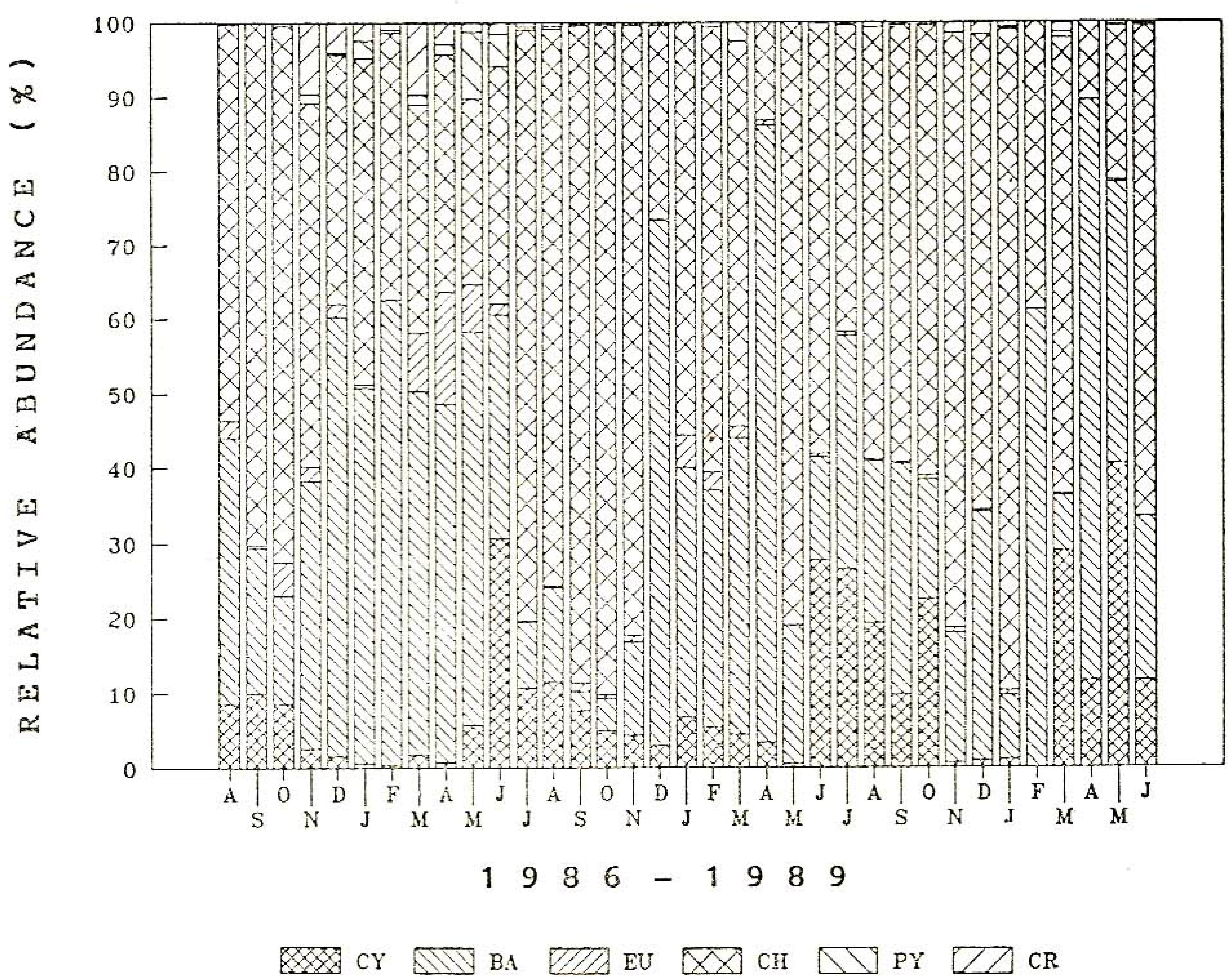

Fig. 7. Variation in relative abundance (%) of the main phytoplankton groups in the KD pond during the time of study. Cy=Cyanophyta; BA=Baccilariophyta; EU=Euglenophyta; CH=Chlorophyta; PY=Pyrrhophyta; CR=Cryptophyta.

other aquatic environments of Taiwan, usually in winter and early spring. The filamentous centric diatom *Melosira granulata* had been a dominant species for a long period of time. In winter and spring of 1986/1987, an another centric diatom, *Cyclotella meneghiniana*, had been a subdominant one. In subsequent seasons, this species became less important with relative abundance rarely more than 5%.

Cyanophyte usually occurred in summer or late spring. *Microcystis aeruginosa* and *Oscillatoria subbrevis* contributed the main biovolume of this group of phytoplankton. The former species became more important regularly in early summer. However, it never formed water bloom during the time of study.

There presented some cryptomonads and dinoflagellates in this pond. Cryptomonads usually had main growth period between autumn and spring and dinoflagellates in spring and summer. Neither of them appeared with relative abundance higher than 4%.

Species of phytoplankton and their relation to water quality

Among the phytoplankton species found in this pond, some of them are of either beta- or alpha-mesosaprobic indicator (Table 1). The species listed in the

Table 1. List of phytoplankton species in the KD pond indicating the state of different saprobities

Saprobity class	Species
Beta-mesosaprobity	*Merismopedia tenuissima*
	Microcystis aeruginosa
	Spirulina platensis
	Melosira granulata
	Euglena acus
	Euglena oxyuris
	Phacus pleuronectes
	Strombomonas verrucosa
	Trachelomonas hispida
	Trachelomonas volvocina
	Botryococcus braunii
	Crucigenia tetrapedia
	Dictyosphaerium pulchellum
	Eudorina elegans
	Eutetramorus fottii
	Oocystis lacustris
	Pediastrum div. sp.
	Scenedesmus div. sp.
	Tetraedron caudatum
	Tetraedron minimum
Alpha-mesosaprobity	*Oscillatoria tenuis*
	Phormidium foveolarum
	Cyclotella meneghiniana
	Navicula rhynchochephala
	Euglena geniculata
	Euglena spathirhyncha
	Lepocinclis ovum
	Phacus longicauda
	Cryptomonas erosa

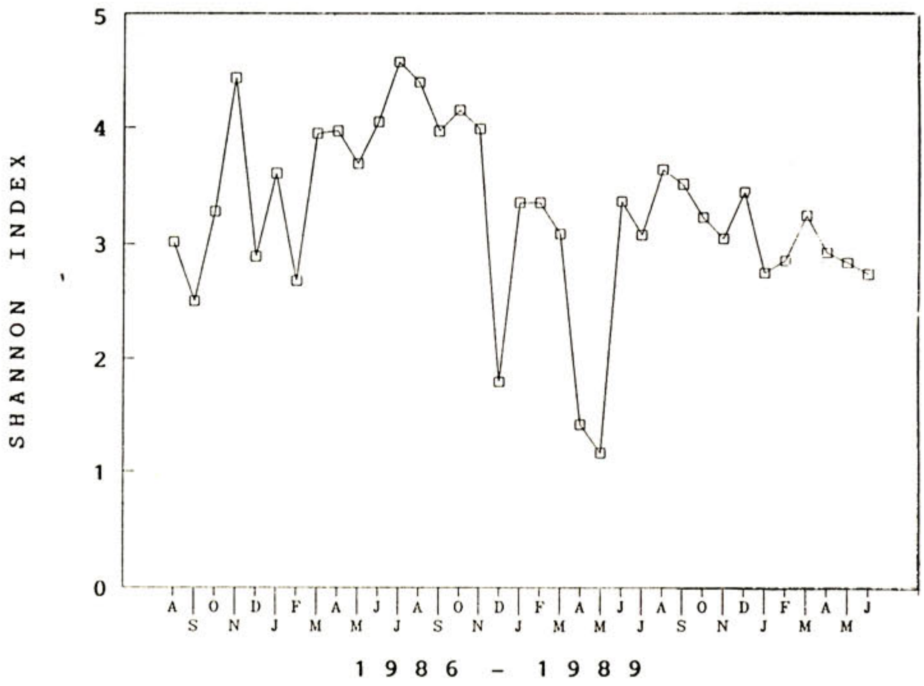

Fig. 8. Variation of species diversity indices of phytoplankton assemblages in the KD pond during the time of study.

table usually co-existed. This indicates that the water quality of this pond varied between these two saprobic levels throughout the time of study.

Variation in the species diversity of phytoplankton assemblage

The species diversity evaluated by Shannon index fluctuated to some extent during the time of study. Mostly, it varied between 2.5 and 4.5 (Fig. 8). There were two marked decreases in diversity, in December 1987 and April/May 1988. These were resulted from the pronounced increase in *Melosira granulata* and *Pediastrum* spp.. The lowering in diversity indices was revealed to be related to the marked increases of ammonium and phosphate content respectively.

DISCUSSION

Phytoplankton are the major source of DO in aquatic environments. In the meanwhile, phytoplankton consume also DO and serve therefore as the major sink for oxygen in the pond. DO level depends thus primarily on the relative magnitude of photosynthetic oxygen generation and total plankton respiration. A higher DO concentration was predicted to be produced by an intermediate densities of phytoplankton rather than a higher density of them (Smith and Piedrahita, 1988). The comparison of them in this pond shows that DO did not increase when phytoplankton density increased. Actually, the highest DO was measured at the beginning of study time, at which phytoplankton was as low as 1.0×10^4 cells per ml. A decline in DO content was measured when the density of phytoplankton increased. This meets thus with the fact mentioned by previous authors.

The concentration of phytoplankton in the pond depends on a number of factors: above all, the grazing pressure, nutrient and temperature. The grazing pressure exerted by different zooplankton species is one of the important selection factors deciding the occurrence of phytoplankton species (Schoenberg and Carlson, 1984). The characteristics of zooplankton occurred in this pond had been briefly described by Lei *et al.* (1989). Rotifera such as *Brachionus* div. sp., *Polyarthra* sp., *Keratella cochlearis* var. *tecta* and protozoan *Tintinnidium* sp. were the main components of zooplankton in the pond. However, it is still unclear, how did these zooplankton influence the composition of phytoplankton assemblage in the pond. The available information is still inadequate to elucidate this relationship.

The maximum of phytoplankton density in this pond was developed toward summer. This is somewhat different from those reported in temperate zones (Jenkerson and Hickman, 1984; Munawar and Munawar, 1986; Renolds, 1986; Sommer, 1986). The summer maximum of phytoplankton density was a general phenomenon in water reservoirs of this subtropical island (Kuo *et al.*, 1991). Nevertheless, the effect of seasons on the variation in phytoplankton biomass in this pond was not so evident as it had been observed in oligotrophic or other eutrophic water reservoirs of this island (Wu and Chang, 1991). It is likely that such a phenomenon is related to the trophic state of a water. Generally, the periodical variation of phytoplankton biomass in this subtropical island was less evident in eutrophic water reservoirs than in oligotrophic one.

The species of phytoplankton appeared in the pond were related to the quality of water. The quality of water can be assessed from the analysis of phytoplankton assemblages. According to the classification of Sládeček (1973), the species of phytoplankton appeared in this pond were either of beta- or of alpha-mesosaprobic indicators. Both types of organisms usually coexisted. The same phenomena were also observed in the zooplankton assemblages. Among the dominants of zooplankton assemblages (Lei *et al.*, 1989), *Brachionus angularis*, *B. diversicornis*, *B. forticula*, *B. plicatilis*, *B. quadridentatus* and *Keratella valga* are the indicator for beta-mesosaprobity and *B. calyciflorus*, *B. rubens* and *Rotaria* sp. are indicator for alpha-mesosaprobity (Sládeček, 1983). Both of the results met well with each other and indicated that the water quality of this pond is between these two saprobic levels.

Nutrient is the another factor which strongly affect the growth and type of phytoplankton assemblages (Rhee, 1982). In freshwater ecosystems, N and P are the most important nutrients for the growth of algal cells. Terry *et al.* (1985) had indicated that N/P ratio can be used to determine which nutrient is limiting, but cannot be used to determine relative growth rates or competitive advantage between species. The analysis of water quality of this pond shows that the N/P ratios fluctuated without markedly relating to the occurrence or disappearance of a definite species within phytoplankton assemblages. Possibly, the individual concentration of N or P in this hypereutrophic pond was so high that neither of them became a limiting for the growth of phytoplankton cells. In such a hypereutrophic pond, it is likely that *r*-selection plays more important role than K-selection in determining the competition of species within phytoplankton assemblages.

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臺灣北部一中型優養蓄水庫內浮游藻之週期變化特性

吳 俊 宗

摘 要

本文探討臺灣北部一中型蓄水庫內浮游藻在 1986 年 6 月至 1989 年 7 月間之藻種及羣落之週期性變化特性。本文就水質理化參數及浮游動物數量之變化探討其與藻種及羣落之週期性變化的關係，結果顯示，浮游藻雖在夏季數量最高，但隨季節消長之現象並不明顯，而與其它水庫情形略有不同。浮游動物之數量常隨浮游藻數量增加而上昇，顯示浮游藻數量增加非因攝食壓力之減低所致。從水中理化因子分析及以浮游藻爲水質指標均顯示，此水域爲過優養狀態，水中營養源濃度甚高，加以冬季氣溫溫和，被認爲是導致浮游藻數量不隨季節消長而明顯變化之主因。