Verh. Internat. Verein. Limnol.	27	152–156	Stuttgart, April 2000

Seasonal succession of phytoplankton in a small oligotrophic oxbow and some consideration to the PEG model

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Introduction

Most of the research on the structure and dynamics of phytoplankton in lacustrine environments was performed in larger lakes. In small lakes, especially oxbows in which there is a profusion of waterbodies, available information is scarce (REYNOLDS 1993). Phytoplankton seasonal succession is discussed by comparison with the world model for lakes, PEG (Plankton Ecology Group, SOMMER et al. 1986). This model consists of 24 sequential statements, which describe, step by step, the seasonal events, which occur in phytoplankton and zooplankton of an idealised standard lake (Lake Constance). These statements have been tested using data from 24 different lakes, none of which were oxbows. The objectives of this paper are to describe the phytoplankton structure and to discuss the main patterns of seasonal variations of the phytoplankton species of a Hungarian oxbow. The present article is the first concerning an oxbow phytoplankton community and discusses data in relation to the steps proposed by the PEG model

Materials and methods

The investigations were performed at Kecskészugi-Holt-Körös, Körös area, Békés county, SE Hungary (Latitude N 46° 57' 13.96", Longitude E 20° 49' 28.73"), a small (area, 12 ha; maximum depth, 3.5 m; average depth, 2.2 m) oxbow (PÁLFI 1995). The banks are colonized by *Schoenoplectus lacustris* L. up to 0.8 m depth. *Myriophyllum spicatum* L. and *Potamogeton perfoliatus* L. cover the bottom sediments in regions up to a depth of 1–1.5 m, and *Nitella* sp. at the site of maximum depth. Between June 1995 and October 1996 water samples were collected biweekly. For sampling of the water column, a hard polyvinyl plastic tube attached to an electric pump was used to collect samples from the water column. Phytoplankton samples were preserved with Lugol's solution in the field. Biomass was estimated by cell volume. The biovolume for each species was calculated using the mean dimension of ten specimens for the more abundant species and from literature data for rare species (TAYLOR & WETZEL 1988). The physical and chemical variables have been measured according to COMECON methods (FELFÖLDY 1987). All chemical analyses were carried out within 24 h of sampling.

Results

From June to the beginning of October of 1995 and 1996 the water column was stratified with a well-defined epilimnion, thermocline and hypolimnion (Fig. 1). Turnover was initiated by stormy weather in September, which eventually led to mixing of the water column at a temperature of 15–18 °C in October. The highest surface water temperature (27 °C, Fig. 1) was recorded in mid-August 1996. The difference between epi- and hypolimnion was 9 °C in late-August while in June of 1995 and 1996 it was 6 °C (Fig. 1). From October 1995 to May 1996 the vertical temperature distribution was uniform (Fig. 1). In late-December 1995, the water temperature dropped to 5 °C and a pan of the lake was frozen. The maximum depth during the study period was 3.5 m and Secchi depth varied between 1.5 and 3.5 m. The water was alkaline, with a varying pH of 7.0–7.8 (Table 1). Conductivity ranged between 86 and 402 µS cm^{-1} with the lowest values during spring, rainy periods.

Eighty-three algal taxa were identified. Some algal groups (Chlorophyceae, Zygophyceae, and Bacillariophyceae) were represented by more than five species, while Euglenophyceae were

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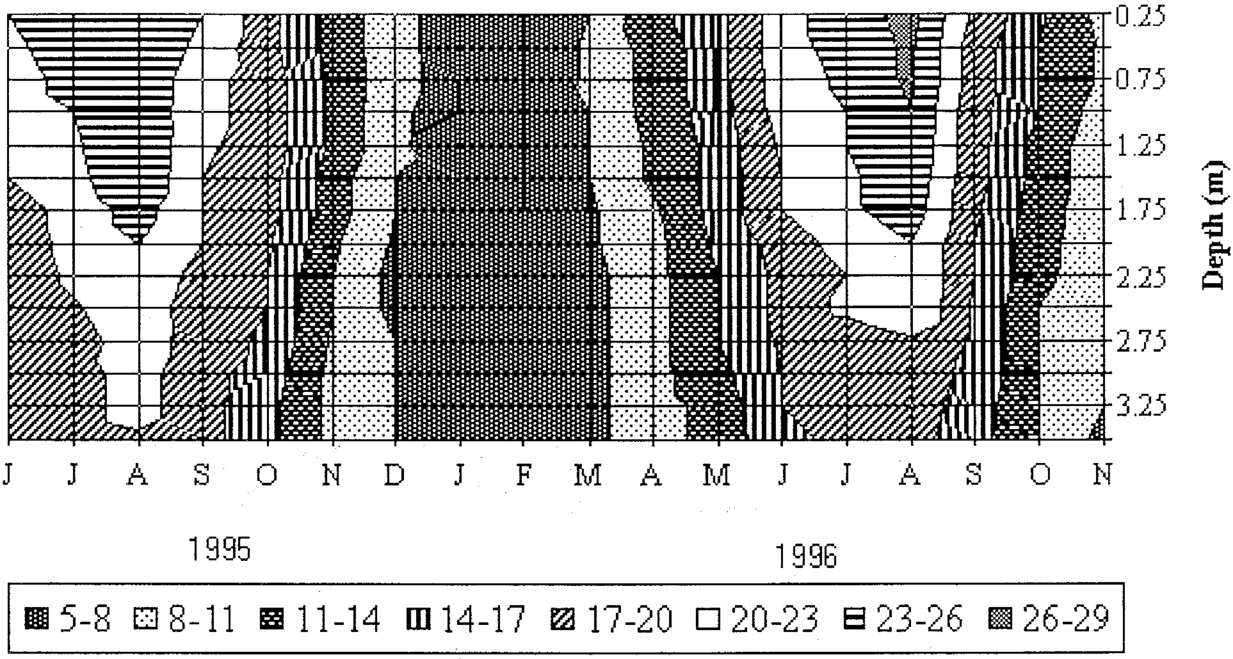

Fig. 1. Time–Depth isotherms (°C) over the studied period.

represented by five species, Dinophyta by four, Chrysophyceae by three, and Prymnesiophyceae and Cyanobacteria by one species each. Total phytoplankton biomass varied (Fig. 2) from 450 to 1,100 μg L^{-1}.

Table 1. Main limnological parameters in Kecskés-zugi-Holt-Körös.

	Mean	Range
Temperature (°C)	12.8	4.8–18.1
pH	7.2	7.0–7.8
Conductivity (μS cm^{-1})	209.0	86.0–402.0
Secchi depth (m)	2.8	1.5–3.5
Oxygen (mg L^{-1})	8.2	7.25–11.2
Alkalinity (meq $L–^{1}$)	0.45	0.36–0.62
Chloride (mg L^{-1})	0.5	0.44–0.68
Calcium (mg L^{-1})	6.4	6.3–6.6
Magnesium (mg L^{-1})	1.8	0.91–2.12
Sodium (mg L^{-1})	3.8	3.1–4.4
Potassium (mg L^{-1})	0.45	0.44–0.47
Sulphate (mg L^{-1})	1.61	0.95–2.21
Total P (μg P L^{-1})	5.3	3.9–12.8
Nitrate (μg N L^{-1})	3.8	0.22–4.2
Nitrite (μg N L^{-1})	0.7	0.11–1.9
Ammonia (μg N L^{-1})	18	2–21
SiO_2 (mg L^{-1})	17.5	12.5–22.8
N/P ratio	36	1.8–140

Algal biomass was mainly represented by the Dinophyta group, *Ceratium hirundinella*, *Peridinium palatinum*, *Peridinium cinctum* and *Peridinium bipes* (especially between June 1995 and March 1996) and by diatoms (between April 1996 and June 1996). The biomass of Dinophyta was high throughout the year which resulted in an important contribution to the total biomass (from 15 to 80%). Diatom contribution to total biomass varied from 10 to 50%. Of the eighty-three taxa registered in Kecskészugi-Holt-Körös, only 11 are important to describe the seasonal variations of the phytoplankton since they contributed more than 5% to total phytoplankton biomass (Fig. 3). Chlorophytes were dominant only in summer and early autumn, forming 28% of the total biomass. The chlorococcal *Ankistrodesmus falcatus* contributed 7% to the total biomass. It was present at the end of September. Other Chlorophytes with small peaks during the summer were *Scenedesmus quadricauda* and *S. ecornis*, although their contributions to total biomass were below 5%. The desmid *Staurastrum paradoxum* represented 9% of the total biomass during its maximum in late summer. No species of the Cyanobacteria group contributed substantially to the total biomass. Cryptophyta *(Cryp-*

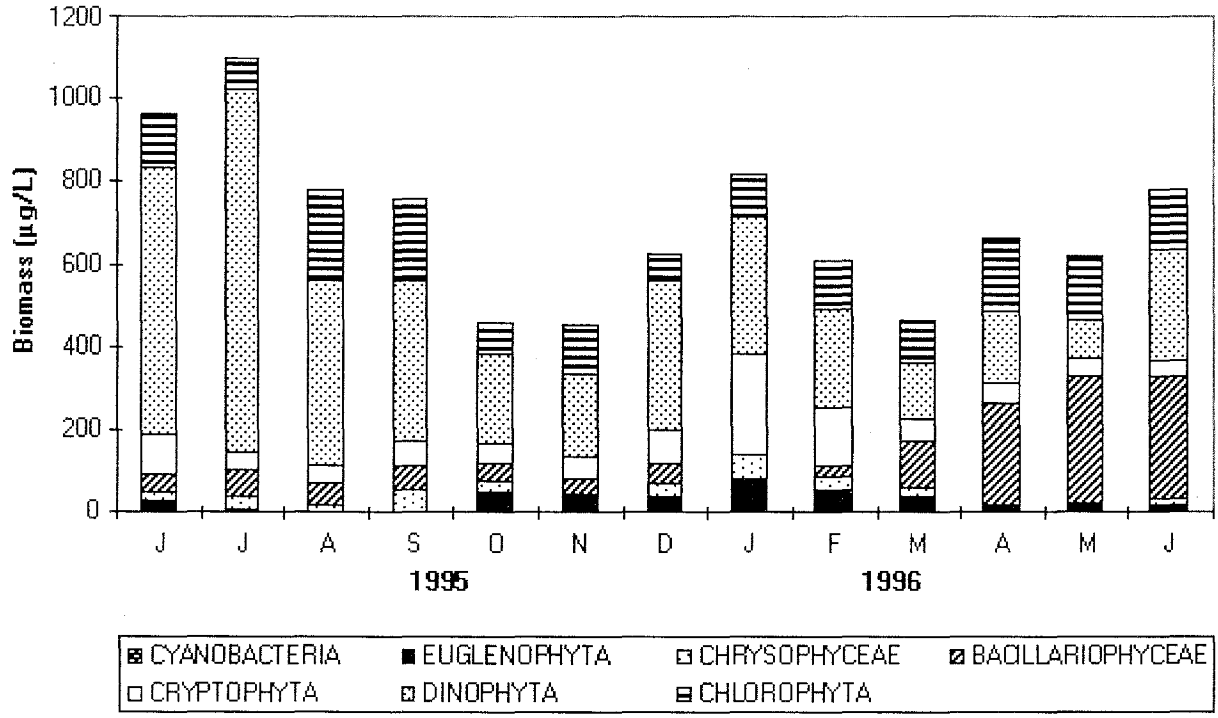

Fig. 2. Total phytoplankton biomass during the investigation.

tomonas ovata and *C. erosa*) were present only during the early summer and winter, contributing 10–30% to the total biomass. The only species of the Prymnesiophyceae group, *Chrysochromulina parva*, contributed up to 1% of the total biomass.

The populations of the Chrysophyceae group were present mainly during the winter and autumn. *Dinobryon sertularia* was abundant (5–7% of the total biomass) during the autumn of 1996. *Mallomonas tonsurata* was present during the winter and part of spring (5% of the total biomass). *Ceratium hirundinella* was dominant during the summer and fall, peaking toward the end of the summer and reaching its lowest value in winter. Its contribution to the

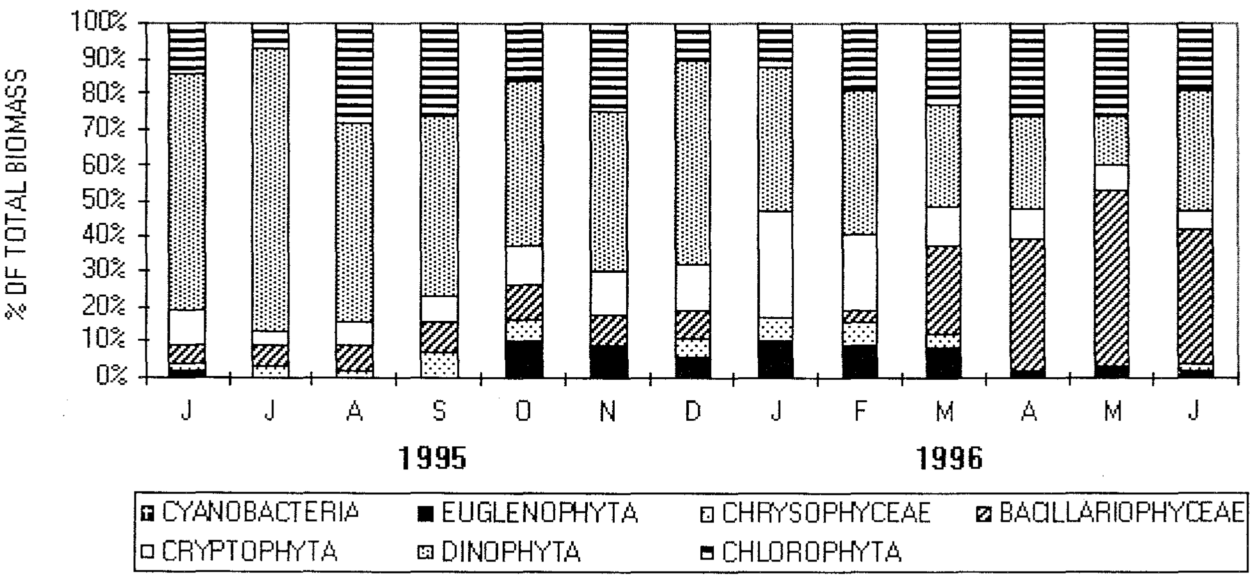

Fig. 3. Total phytoplankton percentage of biomass of the major phytoplankton groups over the investigation.

total biomass was very important (being 79% of the total in July 1996). The large cells of diatoms such as *Aulacoseira granulata*, were dominant, contributing 18–42% of the total biomass during spring. Two euglenoids were occasionally dominant, *Euglena acus* and *Trachelomonas* spp., with peaks in January (10% of the total biomass).

Discussion

Kecskészugi-Holt-Körös can be described as a shallow, oligotrophic (low chlorophyll *a* and organic matter content), monomictic water body with stratification during the summer months. The chemical composition of Kecskészugi-Holt-Körös corresponds to a dilute solution dominated by dissolved silica and calcium bicarbonate. Those characteristics would be typical of Hungarian oxbows, which can be attributed to the dominant igneous nature of the bedrock. Silica concentration in Kecskészugi-Holt-Körös is higher than the average for lakes included in the PEG model. During winter Kecskészugi-Holt-Körös showed an increase of inorganic nitrogen (nitrates and ammonia). Later on with the increase in daylight in spring 1996, development of algal biomass was favoured, which was represented by 50% of diatoms (mainly *Aulacoseira granulata*) and 25% of Cryptophyta plus Chrysophyceae (*Dinobryon sertularia*) plus Prymnesiophyceae (*Chrysochromulina parva*). Chlorophyta (especially *Scenedesmus* and *Pediastrum*) also increased their abundance and biomass (10% of the total). All these species are described by Reynolds (1987a,b) as pioneers (R strategists). This event coincided with statement 1 of the PEG model. This period of low phytoplankton biomass with good abiotic growth conditions (availability of light and nutrients) could resemble a clear water phase. After that, the phytoplankton biomass began to increase. In both November of 1995 and 1996 different inedible algal groups were present. In November 1995 dinoflagellates constituted 74% of the total biomass, while in 1996 dinoflagellates were 30% and diatoms 50% of the total biomass, respectively. Therefore, this period in general conformed to the steps 4–5 of the PEG model.

Step 9 of the PEG model predicts the dominance of the Cryptophyta–Chlorophyta assemblage during summer. However, in Kecskészugi-Holt-Körös the group composed of Cryptophyta, Chrysophyceae and Chlorophyta only represented 7–17%, Dinophyta being the main constituent in summer months (57–80%). The dominance of Dinophyta could be explained by its resistance to grazing compared to Cryptophyta–Chlorophyta assemblages, while sedimentation would be an important selective loss factor for diatoms when mixing depth is low.

In Kecskészugi-Holt-Körös, phosphorus could be the limiting nutrient (N/P average, 36) during most of the year. Silica was present in concentrations (mean, 17 mg SiO_2 L^{-1}) 5- to 6-fold more than those necessary for the growth of diatoms with values never less than 11 mg L^{-1}. The low nutrient concentration, typical of oligotrophic lakes, restricted the development of green algae and Cyanobacteria. During the stratification period the stability of the water column and the low Si/P ratio restricted the development of diatoms, while nutrients were more available to the motile dinoflagellates. The Dinophyta summer maximum value (77% of total biomass) in Kecskészugi-Holt-Körös was similar to those of eleven other lakes studied under the PEG model.

Total algal biomass decrease began in early autumn (Step 18). *Peridinium* and *Dinobryon* species were dominant. As the model predicts (Step 18), diatoms *Aulacoseira granulata*, become increasingly important as autumn–winter progresses in relation to the complete mixing of the water column and to the increase of the Si/P and N/P (Fig. 3). During mid-winter total phytoplankton biomass was minimum (Step 21 of the PEG model) defining an annual unimodal pattern.

To sum up, though the chemical characteristics of Kecskészugi-Holt-Körös differ only slightly from those given in the PEG model, a specific Dinophyta dominance was obtained in the investigated period. In spite of a high silica content, the low phosphorus levels restricted most of the algal groups, including diatoms. As a consequence, high Dinophyta abundance occurred which coincides with eleven lakes in the PEG model.

Acknowledgements

This study is supported by the Hungarian National Research Foundation (OTKA No. F/5 16455, F/6 23242, F/7 23761), Soros Fundation (No. 247/2/7288), OMFB (Mec/P-0814/98), Magyar Vidékért Fundation (No. II/5-1998).

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