

# USE OF ALGAE FOR MONITORING RIVERS II

edited by

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Proceedings of an  
International Symposium  
held at the  
Volksbildungsheim Grillhof, Vill near Innsbruck  
Innsbruck, Austria, 17 - 19 September 1995

sponsored by  
**Austrian Ministry of Science, Traffic and Arts (Dept. IV/8b)**

supported by  
**SIL Austrian Section  
Austrian Ministry of Agriculture and Forestry  
Deutsche Gesellschaft für Limnologie  
Bioindicator Commission (IUBS)**

## SAMPLING STRATEGIES FOR PHYTOPLANKTON INVESTIGATIONS IN A LARGE RIVER (RIVER DANUBE, HUNGARY)

Keve T. Kiss, Antal Schmidt, & Éva Ács

### SUMMARY

The results of phytoplankton studies on the Hungarian stretch of the Danube are analysed with the focus on questions of sampling frequency. Phytoplankton samples were taken weekly upstream and downstream of Budapest during a long-term project. Six short-term periods were investigated more intensively, with 4-8 samples/day over a 2-4 day period. The qualitative and quantitative composition of phytoplankton samples were investigated.

It is suggested that the sampling frequency should vary during the year in a large eutrophic river like the Danube. It is important to have up-to-date details of water discharge, too. There is a need to know both the present water discharge and the pattern of probable changes in the near future, using forecasts of the water discharge registration service. In mid-winter the sampling frequency can be monthly. In the adjacent cool seasons, in February-March and in November, sampling should be at a 2-3 week frequency. From April to October the frequency can be biweekly in high water periods (during the floods), but we recommend sampling every 7-10 days under low flow conditions. A special "time average" sampling-method is useful in the low water period.

### INTRODUCTION

The subject of sampling methods for river phytoplankton is a "terra incognita" in many respects. On the one hand, there are only short descriptions of sampling methods in papers on phytoplankton studies of large rivers (Uherkovich, 1969, 1970; Schmidt & Vörös, 1981; Kiss, 1994) and on the other hand, there are only a few comments about interesting questions such as sampling frequency and other recommendations how to take "good samples" in rivers (Schwoerbel, 1966; Reynolds, 1984; Wetzel & Likens, 1991).

The aim of this paper is to summarize current knowledge, especially that based on our own experience with the Danube project. The term "large river" is used here for a lowland river with a minimum water discharge of  $100 \text{ m}^3 \text{ s}^{-1}$  in the growing season and current velocity less than  $1 \text{ (max. 1.5) m s}^{-1}$ .

### MATERIAL AND METHODS

One sample series was taken between 1979-1994, upstream of Budapest, at Göd (river km 1669); the second between 1980-1993 at Baja (near the southern border of Hungary, river km 1479); both are termed here the long-term investigation. Samples were taken weekly from near the surface of the main channel of the Danube at the stream line and fixed with Lugol's iodine solution. Qualitative and quantitative investigations were made by the Utermöhl method (acc. to Lund *et al.*, 1958) with an OPTON Invertoscop-D light microscope. For the determination of

chlorophyll *a* concentration, samples were filtered through glass-fibre filters, extracted with methanol and measured photometrically (Felföldy, 1987). The trophic state of the Danube was characterised by the OECD classification (Ryding & Rast, 1989).

Six short-term periods were investigated at different hydrological situations at Göd, four in July and two in September (1991-1995). Samples were taken at 4-8 h intervals during 2-4 day periods for phytoplankton analysis. Every sample was investigated separately.

All quantitative data on total population density were used for statistical analysis to calculate the "optimal" sampling frequency. First the annual average was calculated from the weekly databases. Then the annual averages were calculated again selecting only every second, third, fourth and twelfth sample, - always starting with the first sample of the respective year. Thus biweekly, three-weekly, monthly and seasonal sampling intervals were simulated. The difference between the annual averages obtained from the different subsets and the annual average obtained from the complete dataset are used as a measure for the appropriateness of the sampling intervals.

1979

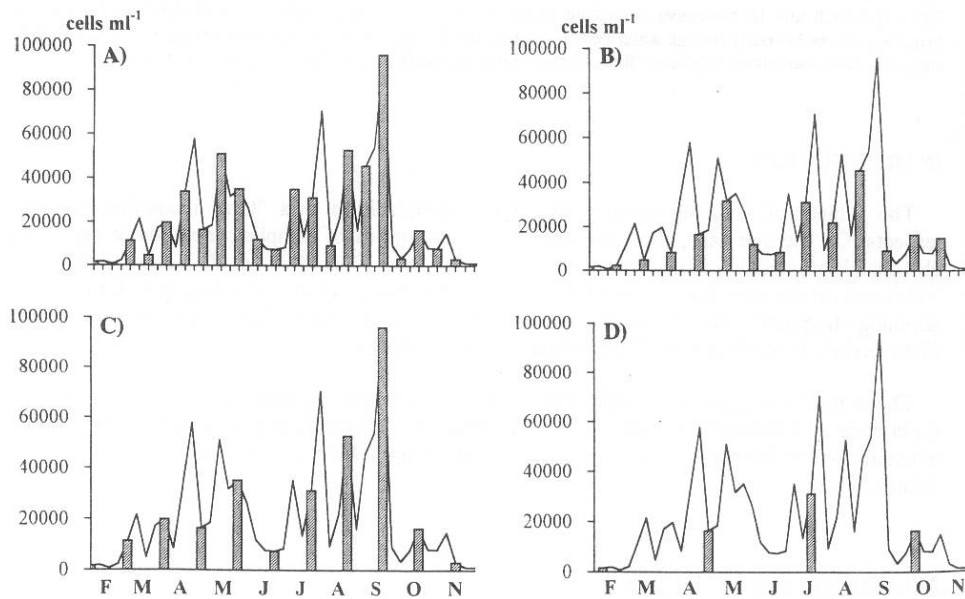


Fig. 1. Change of phytoplankton cell density at Göd in 1979 (line - weekly samples, bars - subsets of samples chosen for simulation of (A) biweekly, (B) three-weekly and (C) monthly sampling intervals as well as (D) simulation of one sampling occasion per season)

## RESULTS

### Long-term investigation

In order to understand the short- and long-term changes in phytoplankton of the Danube it is necessary to characterise the river briefly. The annual average of the water discharge at the Hungarian stretch of the River Danube is about  $2200 \text{ m}^3 \text{ s}^{-1}$  (the minimum approx.  $800 \text{ m}^3 \text{ s}^{-1}$ , the maximum approx.  $8000 \text{ m}^3 \text{ s}^{-1}$ ). The current velocity is typically about  $1 \text{ m s}^{-1}$ , but decreases by 20% under low flow conditions and increases by up to 30-40 % during floods. Floods occur first of all in late spring during the growing season.

The Danube is a potentially hypertrophic water on the basis of nutrient supply (average inorganic N  $2.85 \text{ mg l}^{-1}$ , average  $\text{PO}_4\text{-P}$   $0.185 \text{ mg l}^{-1}$ ; Varga *et al.*, 1989; Déri, 1991). It can therefore become hypertrophic at any time during the growing season, if the hydrological situation is favourable for this (Kiss, 1994). In the Danube the proliferation of phytoplankton is controlled first of all by the floods. During the flood the suspended matter content of the river is relatively high (about  $100 \text{ mg l}^{-1}$ ), thus the transparency is low and the light climate unfavourable for rapid growth of phytoplankton. After the flood the suspended matter content decreases quickly (to about  $20 \text{ mg l}^{-1}$ ), the water-column can become transparent almost to the bottom and the phytoplankton density can double in a few days (Bothár & Kiss, 1990; Kiss 1984, 1994).

1986

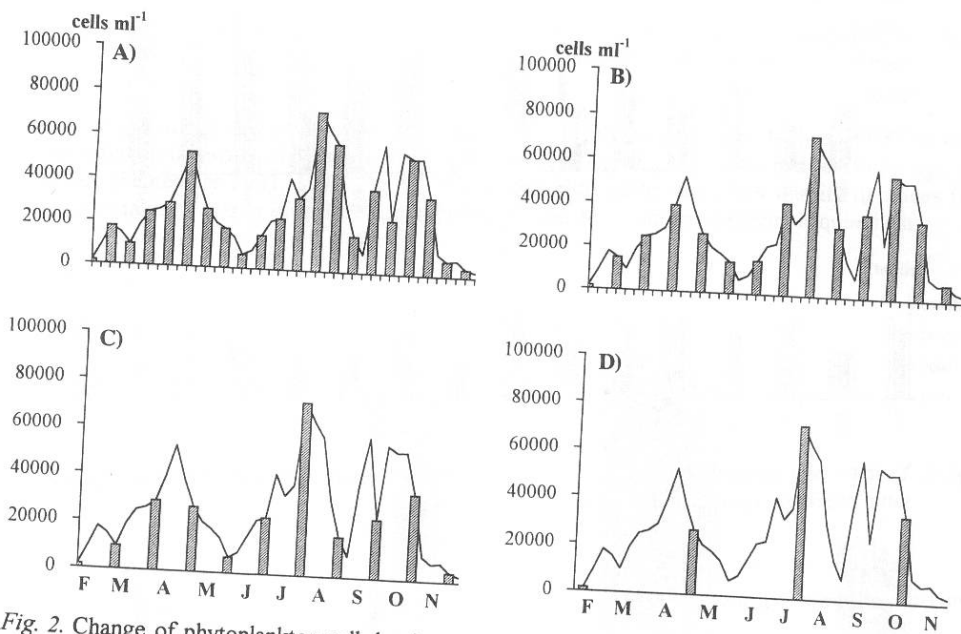


Fig. 2. Change of phytoplankton cell density at Göd in 1986 (Explanation of bars and lines see Fig. 1).

Data from two years were selected from the long-term study at Göd to show the effect of different hydrological situations (Figs. 1, 2). In 1979, when there were many large floods, the phytoplankton density changed quickly (Fig. 1). More than 10 peaks were detected from March to November. The low values were about a few thousand cells per ml, and the high ones ranged

from  $20$  to  $90 \times 10^3$  cells  $\text{ml}^{-1}$ . If we take every second datapoint for analysis, only three peak values are lost and the general variation pattern is still detectable. Use of only every third or fourth data-point leads to a loss in the main characteristics of the seasonal changes. Important information about the phytoplankton density is lost by taking samples only seasonally.

In 1986 when there were only a few large floods, five peaks were registered and phytoplankton density changed relatively slowly (Fig. 2). If the values for every second and third week are omitted, both short-term and seasonal changes could be registered more or less satisfactorily in this year. However, the monthly and seasonal data-series were not characteristic for the phytoplankton changes.

To compare this kind of data-series in different years at Göd and Baja, the mean values for cell density are shown in Fig. 3, using 1-4 weekly and seasonal data. Relatively small differences were registered between the mean values in years characterized by moderate change in water-discharge (1980, 1990) and relatively large ones in years with large fluctuation in water-discharge (1979, 1985). Comparison of data-series at Göd and Baja could of course show differences between the two sampling stations in the same year.

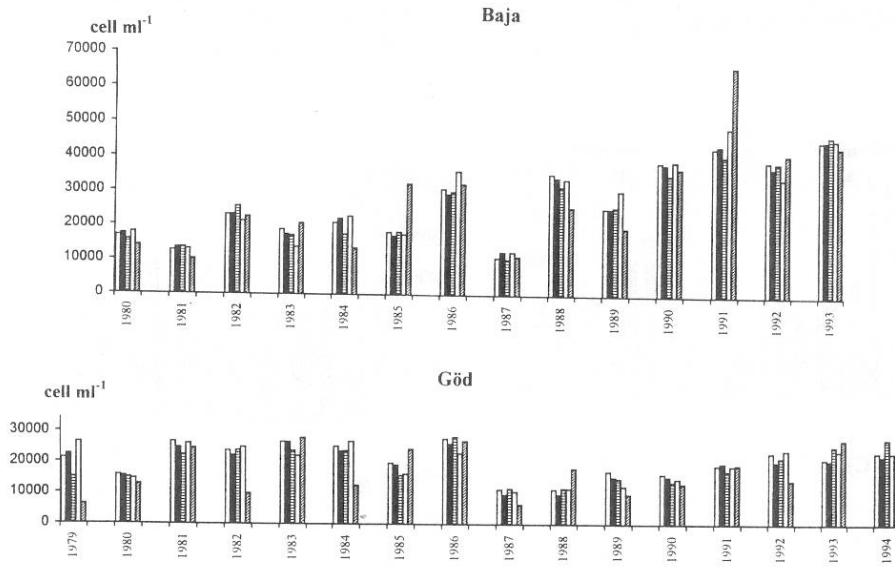


Fig. 3. Year-to-year variability of annual average cell densities calculated from subsets differing in sampling intervals at Baja and Göd.

#### Short-term investigations

The phytoplankton density and the chlorophyll *a* concentration varied in different hydrological situations. The lowest values were registered on 24-26 July 1991 when water discharge was 20-25 % higher than the summer average (summer average of the last ten years,  $2135 \text{ m}^3 \text{ s}^{-1}$ ). The highest values were measured on 27-30 July 1992 when the water discharge was 40-45 % less than the summer average. A minimum of chlorophyll *a* concentration was registered in the morning and a maximum in late afternoon (Fig. 4). The amplitude was low at low chlorophyll *a*

concentration and high when chlorophyll *a* concentration was higher than  $50 \mu\text{g l}^{-1}$ . The wavelength was relatively constant and regular.

The biomass of centric diatoms was high during the low water period ( $23.7 - 44.5 \text{ mg l}^{-1}$ ) and low at time of floods ( $2.15 - 4.5 \text{ mg l}^{-1}$ ). The biomass of total phytoplankton was  $27.9 - 48.2$  and  $3.17 - 6.0 \text{ mg l}^{-1}$  respectively. The centric diatoms formed the 65-85 % of the total algal cell count. The fluctuation of biomass was the same as that of chlorophyll *a*, with a minimum in the morning and with a maximum in late afternoon in 24-26 July 1991. However two maxima appeared on 28 July 1992 (one maximum at early morning and one in the afternoon). The two daily waves were caused by diatoms (Kiss, 1996; Kiss *et al.*, in press).

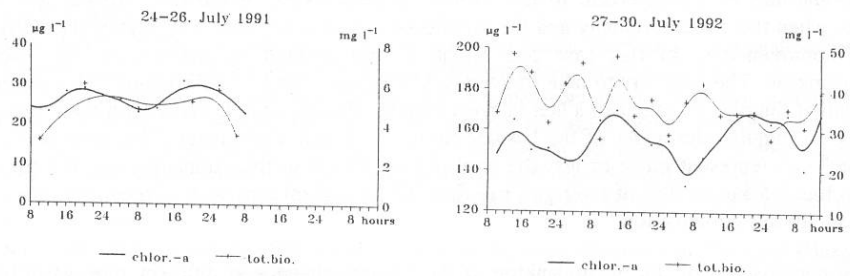


Fig. 4. Diurnal changes of chlorophyll *a* concentration and total biomass of phytoplankton at Göd during a high flow period (July 1991) and a low flow period (July 1992).

Analysis of our data in the same way as it was done with the long-term data-series, shows that the variation in mean cell density can be low on some occasion (July 1991) and relatively high on others (September 1991, 1992, Fig. 5). The deviation from the mean cell density of values for samples taken 8-hourly is negligible, but the range from minimum to maximum is quite high.

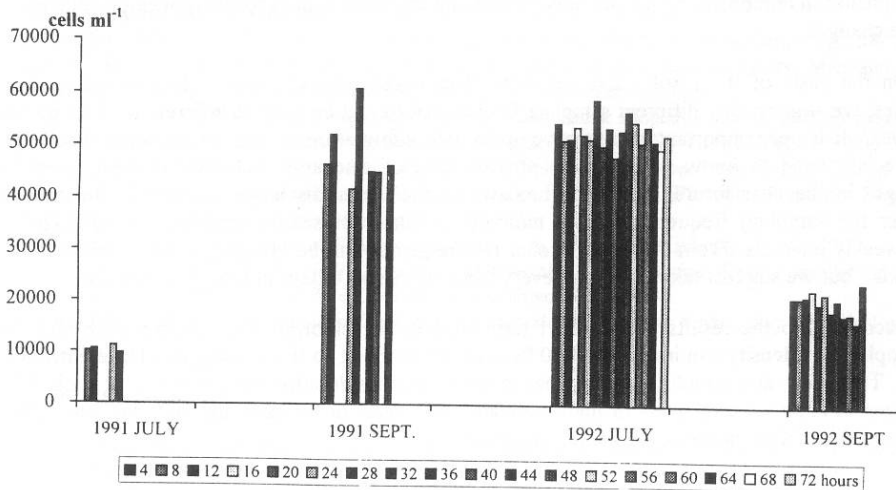


Fig. 5. Average cell density of samples during the short-term investigations at Göd based on sampling at 4-hourly (1992) or 8-hourly (1991) intervals compared to averages of data subsets simulating larger sampling intervals.

## DISCUSSION

Theoretically it is impossible to propose a generally applicable sampling method for rivers, but the case of the middle stretch of the Danube provides a good example, which is likely to be applicable in many cases. The most important question is how to take "representative" sample from the main arm of a large river. In order to answer this question, we will show some aspects of the problem.

The phytoplankton of the Danube is relatively homogeneous in high flow periods, but inhomogeneous in low flow periods. Under high flow the turbulence homogenizes the water and homogenizes the phytoplankton except close to the shore. Therefore one sample taken in the stream-line can be characteristic to the "whole" phytoplankton of the river. In the low flow period, when the current velocity and the turbulence are relatively low, the phytoplankton is not really homogeneous. In this case one sample is not enough to characterise the "whole" phytoplankton. The best way to take an average sample is to get a "time average". This means to take partial samples: to take half a liter in every minute 10 times and fill a tank with these samples. During 10 minutes the water of the Danube flows about half a kilometer. Therefore this "time average" can represent more or less the total phytoplankton of the sampling time. We suppose that in this 0.5 km stretch of river you can find "all phytoplankton" with different densities and different species composition.

The composition of the phytoplankton of the Danube changes at different rates at different seasons (Kiss 1991, Kiss et al. 1993, Kiss & Genkal 1993). The taxonomic and quantitative composition of phytoplankton changes more slowly in late winter and early spring than in summer. We found that it also takes a few weeks in summer for a relatively marked change in taxonomic composition to occur. Several rare species can of course be present in one sample and absent in others. The quick change in quantitative relations needs only about a week in the cool season but only a few days in summer (in this respect cool season means February-March and November). Therefore in warm seasons there is a need to take samples more frequently than in the period from late autumn to spring. Clearly, if samples are taken more frequently, changes in phytoplankton composition will be known better and the same applies to the processes influencing these changes.

On the basis of the results and our more than twenty years' experiences concerning river studies, we suggest that different sampling frequencies should be used at different periods during the year. It is very important also to have up-to-date information on changes in water discharge. There is a need to know not only the present state of discharge, but also its most probable changes in the near future, based on forecasts by the water discharge registration service. In winter the sampling frequency can be monthly. In the cool season samples can be taken in 2-3 weekly intervals. From April to October the frequency can be biweekly in high flow periods (floods), but we suggest taking samples every week or every 10 days in low flow periods.

According to the results of the short term studies, the chlorophyll *a* concentration and the phytoplankton density can increase 20-40 % from the morning to the evening in a large eutrophic river. Therefore, any sampling strategy has to take into consideration the possibility of such daily changes. It is possible to over- or underestimate cell density or biomass and also the chlorophyll concentration (Kiss, in press; Kiss *et al.*, in press).

## Acknowledgement

This study focused on investigations at Göd was supported by the Hungarian National Science Foundation (OTKA, No 934, T 5342 & T 016835).

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