Seasonal and long-term changes of phytoplankton abundance in the Bulgarian-Romanian Danube River stretch

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Introduction

Phytoplankton investigations in the Bulgarian-Romanian Danube River stretch started in 1960 (Wawrik (1962)). Since than, about 20 uncoordinated studies, rather diverse in duration, approach, sampling frequency etc. have been carried out. Despite the irregular sampling, a certain increase in eutrophication level based on phytoplankton composition and abundance, though expressed in various units, has been observed (Naidenow (1995), Kusel-Fetzmann (1998), Stoyneva (2002)). Using the compilation of published and official data of monthly chlorophyll-a (chl-a) measurements over the last 5 years, the objective of this paper is to establish and present the seasonal and long – term temporal trend of phytoplankton abundance changes along the Bulgarian – Romanian section of the Danube River.

Materials and methods

The compiled data from published literature and Bulgarian Ministry of Environment and Waters (BMEW) were presented by three different measures: chl-a, numerical and biomass abundance. Numerical abundance was expressed either by cell number (Stoyneva (1991), Stoyneva &Draganov, (1994)) or by individual number (Naidenow & Saiz (1985), Saiz (1990), Kiss (1991)). Buijs et al. (1992) and Kalchev et al. (1996) extracted chlorophyll in acetone and calculated it by the SCOR-UNESCO formula. Recently the ISO standard in ethanol extract was more frequently applied (Nemeth et al., (2002), monitoring program of BMEW). BMEW kindly provided ISO chl-a data from the years 2001, 2002, 2004 and 2005, sampled at the initial and final sites of the stretch (Pristol – Novo Selo and Chiciu - Silistra). Chl-a is being measured in water samples taken monthly from left, right bank and from the mddle of the river. An acceptable comparability of listed quantitative phytoplankton variables seems possible due to relatively limited changes of average cell biovolume or average individual biovolume of Danube phytoplankton leading to strong correlations between chl-a, biomass and numerical abundances (Kalchev (2000)).

The conversion of numerical abundances reported by Wawrik (1962) and Kiss (1991) into biomass was comprehensively presented in Table 1. The chl-a data obtained by Buijs et al., (1992) were converted into biomass by means of equation BM=-1,167 + 0,349 chl-a, R=0,945, n=23, based on original values of Kalchev et al (1996). The chl-a data obtained from the BMEW were converted into biomass by means of the regression between both variables based on data published by Nemeth et al. (2002) for the 834-375 km-river stretch, which was more appropriate because in both cases chl-a was determined by ISO procedure (BM = 0,525 + 0,195 chl-a with R= 0,758, n=15). A comparison with a regression derived between BM and vital chl-a in acetone extract from years 1989-1990 (Kalchev et al (1996) BM=0,312 + 0,419 chl-a R=0,92) showed that the latter delivered a higher BM than that from ethanol extraction due to the high efficiency of ethanol to extract chl-a. A polynomial calculation was applied for deriving a seasonal pattern of chl-a. Then by subtracting the

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predicted by the polynomial chl-a or BM month values from the original ones we obtained the long-term trend. Also linear regression, correlation and non-parametric Wilcoxon paired sample test were applied.

Table 1 Summary information derived from sources used for collection of phytoplankton abundance data

Data sources	Time of sampling	Sampled Stretch, km	Registered variables	Applied conversions to BM	Number of sites sampled
Wawrik (1962)	Sep-1960	833-375	Abundance cells ml^{-1}	0,124 ng. $cell^{-1}$ after Kalchev (2000)	7
Naidenow & Saiz (1985)	Aug-1978	499-435	Abundance, BM		5
Kiss (1991)	Sep-1978 Mar-1988	834-400 791-376	Abundance Ind.1000 l^{-1}	1,63ng.ind^{-1} calculated from data of Saiz (1990)	4 5
Naidenow & Saiz (1985)	Nov-1978	538-435	Abundance BM		8
Stoyneva (1991)	Aug-1982 Jan-1987 Apr-1987 May-1987 Jun-1987 Aug-1987 Sep-1987 Nov-1987 Jan-1988	792-375 742, 598 794-784 498-488 745-741 454-375 595-550 598, 560-375 792-741 597-595 792-375 792-375	Abundance , BM		29 2 18 15 4 15 9 20 19
Saiz (1990)	Mar-1988	791-384	Abundance, BM		4
Kalchev et al. (1996)	Sep-1989 Sep-1990	834-381 516-381	Chl-a, Abundance, BM		8 4
Stoyneva & Draganov (1994)	Apr-1990	834-380	Abundance, BM		12
Buijs et al. (1992)	Jun-1991	834-375	Chl-a	Chl-a into BM, after Kalchev et al. (1996), see text	13
Nemeth et al. (2002)	Sep-2001	834-375	Chl-a, BM		15
Bulgarian Ministry of Environment and Waters	all months of 2001,2002, 2004,2005	834, 381	Chl-a	Chl-a into BM, regression from data of Nemeth et al (2002), see text	2

Results and discussion

No significant difference was observed between chl a concentration in samples taken from left and right bank, or form the middle of the river. No seasonal pattern (Fig.1A) was recognized at sampling site Pristol – Novo Selo, probably as a consequence of the operation of Iron Gate I and II, as the site is located only 30 km downstream. However, a clear seasonal pattern (Fig.1B) was recorded at the sampling site 400 km downstream of the Iron Gate reservoirs. Then as described in the Material and Methods chapter the monthly values of the seasonal pattern derived at Chiciu-Silistra site were subtracted from the corresponding original chl-a monthly data of 2001-2005 period at the same station. The removal of the seasonal variations resulted in a smoothed long-term trend of chl-a residuals (Fig.2A) expressing a low, hard to recognize by simple eye but statistically significant linear increase (R=0,25; P=0,0032) of chl-a with the time. The same seasonal trend after conversion from chl-a into biomass units was used for seasonal detrending of literature data. Some years of the long-term biomass trend were presented by single month value while others by several month values (Fig.2B). According to the long-term trend contemporary phytoplankton biomass levels were even reached during the years 1987-1989. The long-term course was accompanied by occasional sharp deviations- the result of the main reservoirs operation after 1971 (Iron Gate I) and after

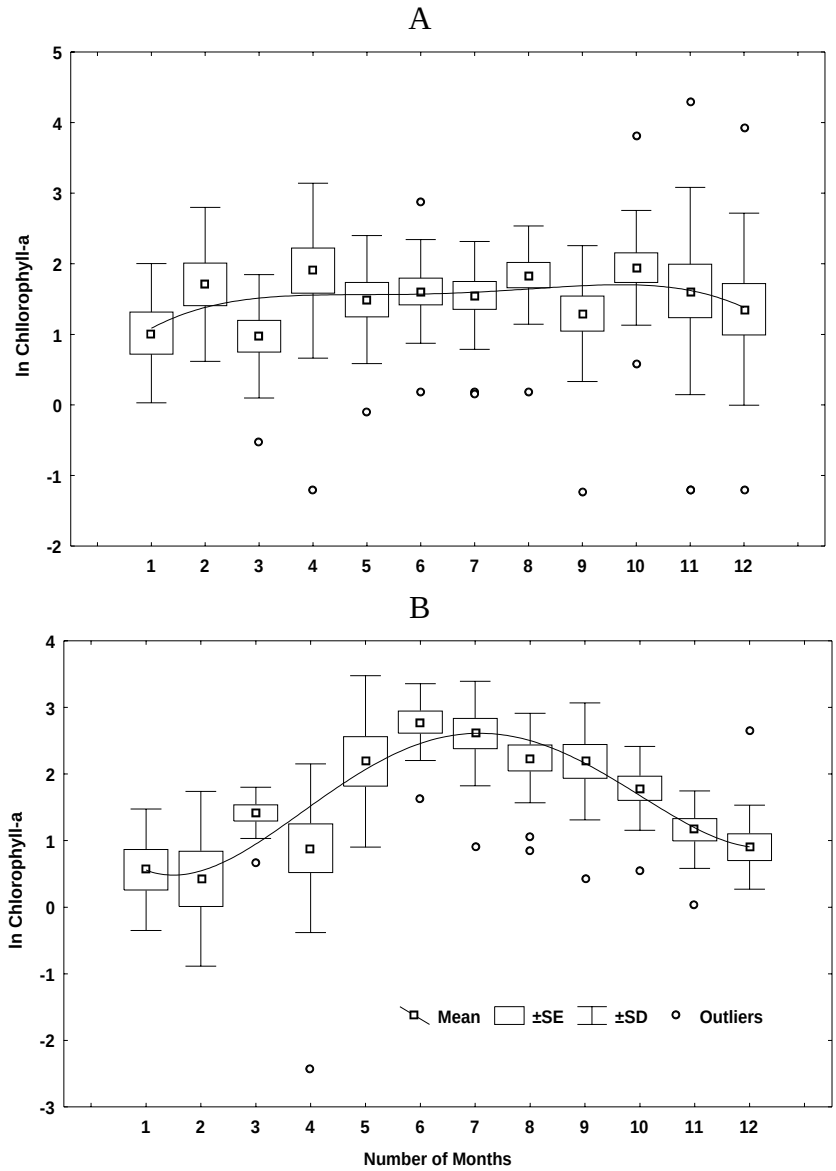

Fig.1 Seasonal variations of chl-a concentrations (mg.m^{-3}) on Pristol – Novo selo (A) and Chiciu –Silistra (B) sites with a seasonal trend on the second site fitted by a polynomial lnChla=1,29-1,2X+0,54X^2-0,064X^3+0,0023X^4, R=0,633, statistically significant for P<0,05.

1983 (Iron Gate II). A comparison with nutrient changes, mostly supposed to enhance phytoplankton growth and more regularly monitored showed, that PO_4-P was low till the 1981-1985 and within 1995-1995 periods and remained approximately at the same high level during 1988-1990 and after 2000 (Kalchev et al under review). The NO_3-N varied to lower degree than PO_4-P, being partly lower before 1985 than it was after 1988 when it was stabilized at relatively higher level than in previous years. Thus the observed phytoplankton abundance increase till 1988 seemed well founded by the corresponding nutrient increase, mainly due to PO4-P. In that sense the low PO4-P in 1995-1999 period sooner might suppose lower than higher biomasses in this interval distinguished by a complete absence of sampling. In seasonal aspect the summer maximum of phytoplankton development coincides with the minimum of NH_4-N, NO3-N and PO4-P (Kalchev et al under review). Thus in summer nutrients seem to be reduced by phytoplankton, while in long-term aspect the nutrient concentration seems to determine phytoplankton abundance. In spite of the differences in

expressing abundance, seasonal and other sources of variations, Naidenow (1995), Kusel-Fetzman (1998) and Stoyneva (2002) still recognized the accelerated eutrophication process tendency according to the increased abundance and share of green and blue-green algae in total phytoplankton composition.

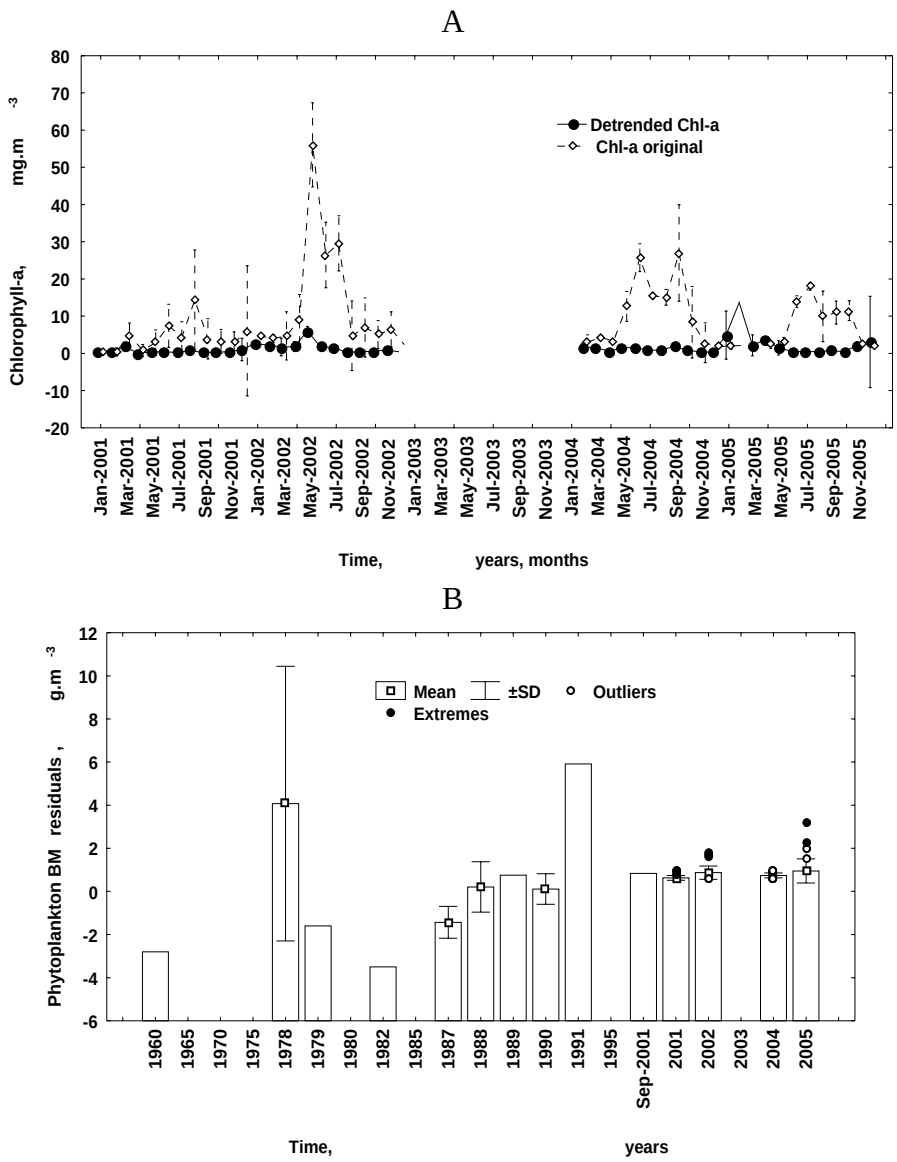

Fig. 2 – Original and long-term trends of chl-a (A) and biomass (B), derived from data on Chiciu - Silistra station or sites closest to it.

Summary

No seasonality was detected in phytoplankton chl-a changes on Pristol – Novo Selo site situated close after Irion Gate Reservoirs, while a clear seasonal pattern emerged 400 km downstream on Chiciu - Silistra site. After seasonality removal the resulting long-term trend supposed an eutrophication increase till the end of 1990, followed by similar biomass levels within 2001-2005 period. Under the assumption that the seasonal trend has remained unchanged over the whole period from 1960 till now, the derivation of the seasonal pattern from last present 3-4 consecutive years and its subsequent extraction from the original historic data seems to be a reasonable approach for evaluation of long-term changes even based on irregular and sparse investigations in the past.

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