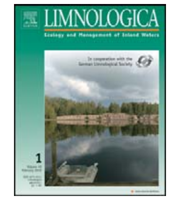
Limnologica 41 (2011) 160–166

Contents lists available at ScienceDirect

Limnologica

journal homepage: www.elsevier.de/limno



Variability of phytoplankton biomass in a lowland river: Response to climate conditions

Blanka Desortová[a,*], Pavel Punčochář[b]

[a] T.G. Masaryk Water Research Institute, Public Research Institution, Prague, Czech Republic
[b] Section of Water Management, Ministry of Agriculture, Prague, Czech Republic

ARTICLE INFO

Article history:
Received 9 April 2009
Received in revised form 8 July 2010
Accepted 27 August 2010

Keywords:
River
Phytoplankton
Chlorophyll-a
Flow rate
Seasonal dynamic
Year to year variation
Climate change

ABSTRACT

The results are presented of an intensive study of phytoplankton assemblage carried out in the Berounka River above its confluence with the Vltava River (Czech Republic) in the period 2002–2007. The annual and interannual changes of phytoplankton development (based on high frequency of sampling) and their relation to hydrological conditions and concentrations of main nutrients are analysed. A marked decline of nutrient concentrations was observed during the period 1996–2007. The annual mean values of total P decreased from 0.43 mg L^{-1} to 0.16 mg L^{-1}, those of N-NO_3 from 4.6 mg L^{-1} to 1.5 mg L^{-1} and N-NH_4 from 1.9 mg L^{-1} to 0.04 mg L^{-1}. Despite this, the phytoplankton biomass remained at a high level. The seasonal mean values of chlorophyll-a ranged from 51.0 μg L^{-1} to 116.8 μg L^{-1} in the same time period. An obviously stronger relationship was found of the phytoplankton biomass and pattern of its development to the variation of flow rates than to the existing level of nutrient concentrations. A significantly decreasing relationship (R^2 = 0.384, P < 0.001) of chlorophyll-a to flow rates and a significantly increasing relationship (R^2 = 0.359, P < 0.001) of chlorophyll-a to water temperatures were found, based on monthly mean values for the seasonal period 2002–2007. The results obtained indicate a remarkable increase of phytoplankton biomass and its prolongated occurrence in watercourses, which can be expected due to the consequences of the predicted climate change (i.e. higher occurrence of summer droughts and low precipitation amounts accompanied by a substantial drop of flow rates, increase of air and water temperatures), as described in the respective scenarios for the territory of the Czech Republic. Simulations by the regional climate models HIRHAM and RCAO and emission scenario SRES indicated the increase of air temperature by 2.5–5 °C, decrease of precipitation amount by 6–25% and decline of flows by 14–43% in the Berounka River for the scenario period 2071–2100.

Introduction

Phytoplankton represents one of the important elements for the assessment of the ecological status of surface water bodies according to the Water Framework Directive (WFD 2000/60/EC). It is the result of the high level of eutrophication in most of the European watercourses due to their loading of nutrients, namely various forms of phosphorus compounds (EEA 2003). The presence of high phytoplankton biomass in surface waters, including streams, is commonly related to an excess of nutrients. With regard to this fact, results of phytoplankton biomass monitoring are primarily used to estimate the level of trophy and development of eutrophication (e.g. Kelly and Whitton 1998; Dodds et al. 1998). However, the controlling role of discharge fluctuations and water temperature in the development of river phytoplankton is reported and nutrients are considered to be less important (e.g. Fruget et al. 2001). Based on the study of the Thames and the Humber Rivers (England), Hilton et al. (2006) and Neal et al. (2006) suggested that residence time and flow conditions determine the growth of algae in river systems.

A number of studies concerned with assessing climate changes impacts on the hydrological regime and quantity of surface waters (e.g. Ludwig et al. 2009). Less information is obtained on the effect of changing climatic conditions on water quality and especially on microscopic organisms in running waters.

Zwolsman and van Bokhoven (2007) summarised long term data on water quality in the River Rhine. They compared changes of water quality variables, including chlorophyll-a concentration, during the long periods of drought in 1976, 1991 and 2003. It was obvious that the chlorophyll-a concentration was much higher during the drought than under average flow conditions in the Rhine. A similar situation was observed when data on chlorophyll-a was analysed for the Meuse River in the drought periods of 1976 and 2003 (Vliet van and Zwolsman 2008). Based on water quality

* Corresponding author. Tel.: +420 220 197 411; fax: +420 233 333 804.
E-mail address: blanka_desortova@vuv.cz (B. Desortová).

0075-9511/$ – see front matter
doi:10.1016/j.limno.2010.08.002

modelling, Fischer et al. (2008) studied how changes of climatic conditions influence nutrient concentrations and phytoplankton growth in the Elbe River from the inflow of the Vltava River to Geesthacht (length of the river stretch = 700 km). They found that, at the present time, phytoplankton development is above all light-limited and depends on the water flow time.

The aim of this study was to detect phytoplankton biomass changes and possible factors which can influence the status of this natural biological component of the aquatic ecosystem in the lowland river Berounka. For this purpose an intensive monitoring of phytoplankton characteristics and several hydrochemical variables was carried out in the years 2002–2007. The hypotheses appointed to test were: (1) the temporal pattern of phytoplankton development is influenced by the meteorological and hydrological variables; (2) phytoplankton biomass is significantly related to flow rate; (3) clear dependency of phytoplankton biomass on nutrient concentrations is not obvious in the river Berounka.

Materials and methods

Site description

The River Berounka (total length of the watercourse 139.1 km) is one of the main tributaries of the River Vltava, upstream of the capital city of the Czech Republic. The River Berounka drains an area of 8861.4 km^2 constituting about 31% of the whole Vltava catchment area. The sampling site was situated about 1.5 km above the confluence of the River Berounka with the River Vltava. As there are no important water reservoirs along the River Berounka and cross structures on the river comprise only several weirs, the manipulation with flow rate is not a significant factor and has no disturbance effect on phytoplankton development. The long-term average annual flow rate near the mouth is 36.0 $m^3\ s^{-1}$. The mean depth of the river at the sampling site is about 0.6 m and the river bed is about 55 m wide.

The River Berounka is an example of a eutrophic, phytoplankton-rich river where phytoplankton biomass reaches up to 280 $\mu g\ L^{-1}$ of chlorophyll-a in the middle and downstream stretches of the river during the seasonal period. According to the Behrendt and Opitz (2001) proposal of river classification, the River Berounka can be classified as a “phytoplankton dominated river”. Phytoplankton biomass transported from the River Berounka down the Vltava River markedly contributes to high chlorophyll-a concentrations in the River Elbe below the confluence with the Vltava (Desortová 2007).

Sampling

Water samples were collected at 2- to 3-day intervals during the growing season (March–October), and weekly out of this period. The number of samples taken varied between 63 and 172 per year for the period of 2002–2007.

Characteristics studied

The variables under study included the amount of phytoplankton (as chlorophyll-a concentration to express the total phytoplankton biomass) and species structure, nutrient concentrations (total P, N-NO_3, N-NO_2, N-NH_4), water temperature and flow rates (daily means), occurrence of precipitation and the sum of sunshine.

Chlorophyll-a concentration was estimated by the spectrophotometric method with acidification procedure (Lorenzen 1967). Phytoplankton taxonomic composition was examined by light microscopy.

Nitrogen compounds (N-NO_3, N-NO_2, N-NH_4) were determined by flow analysis (CFA-continual flow analysis) with the spectrometric detection. Total phosphorus was analysed by optical emission spectroscopy with inductively coupled plasma (ICP-OES method).

Water temperature was recorded at the time of sampling. Data on daily flow rates were obtained, as well as other meteorological characteristics (i.e. total sunshine and precipitation amount), from the web presentation of the Czech Hydrometeorological Institute (www.chmi.cz).

Meteorological and hydrological situation

Concerning the study period (2002–2007), the individual years were significantly different as regards climatic conditions and hydrological situation, as follows from the yearly assessment of the climatic situation for the Czech Republic (CHMI 2002–2007). Based on the average annual air temperatures, the whole monitoring period can be described as a period with above-average temperatures (www.chmi.cz). The years 2002, 2003 and 2007 were, in terms of temperature, significantly above-average (deviation from long-term normal 1961–1990 = 1.3 °C, 0.9 °C and 1.6 °C respectively), the years 2005 (deviation 0.3 °C) and 2006 (deviation 0.7 °C) slightly above-average. The only year with average (normal) temperatures was the year 2004. As regards precipitation amounts and discharge situations, the year 2002 was considerably above-average with consequent occurrence of extreme floods over the whole territory of Bohemia. Even the year 2006 was, in terms of precipitation amounts, above-average with flood episodes especially in the first six months of the year. These were caused by the high snow pack melting in the mountains and later (May) by the high rainfall amount. On the other hand, the year 2003 was extremely dry due to deficit precipitation amounts, in particular during the growing season. A similar situation occurred in the spring of 2007 following a mild winter with lack of snow and a deficit precipitation amount in March and especially in April. The differences between the individual years are illustrated in Table 1 showing for comparison the seasonal means of water and air temperature determined on the basis of measurements taken during sampling. This table is completed by seasonal means and minima of flow rates and seasonal sum of sunshine.

The results of regional studies (Kašpárek et al. 2006) were used to demonstrate possible impacts of global climate changes on climatic events and the water regime in the Czech Republic. The regional climate models HIRHAM and RCAO and the emission scenarios of greenhouse gasses concentrations SRES A2 (pesimistic) and B2 (optimistic) were applied to assess a climate development in the Czech Republic for the period 2071–2100. The reference period was 1961–1990. Outcomes from the model simulations indicate that the mean annual air temperature can increase in the range of 2.5–5 °C, the annual precipitation amount can decrease by 6–25% and minimum mean monthly flows can drop locally to 15% of their unaffected values.

Table 1
Seasonal (March–October) means of temperature, seasonal means and minima of flow rate at the Berounka sampling site and seasonal sunshine sum for the Bohemia territory.

Year	Temperature, °C		Flow rate ($m^3\ s^{-1}$)		Sunshine duration (hours)
	Water Mean	Air	Mean	Minimum	Total amount
2002	15.8	13.2	63.6	15.9	1498
2003	16.1	13.5	23.7	8.3	1865
2004	15.5	12.5	24.6	8.8	1575
2005	15.2	12.7	29.0	9.9	1657
2006	15.5	13.1	43.5	11.3	1638
2007	16.6	13.6	21.7	8.1	1610