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Original Articles

The role of annual periodic behavior of water quality parameters in primary production – Chlorophyll-a estimation

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ABSTRACT

Since phytoplankton is an autochthonous primary producer, it plays a vital role in driving the water quality of rivers and lakes. Therefore, in cases where measurements are lacking, its estimation is of the essence. In the present study, Morlet wavelet spectrum (periodicity) and multiple regression analyses were conducted on 15 chemical, biological and physical water quality variables sampled at 14 sites along the Hungarian section of the River Tisza and 4 sites from artificial tributary channels for 1993–2005. Results show that annual periodicity was not always to be found in the water quality parameters, at least at certain sampling sites. Periodicity was found to vary over space and time, but in general, an increase was observed in the company of higher trophic states of the river heading downstream. Based on the spatial distribution of the periodic behavior of the water quality parameters (runoff, ions, and nutrients given in so-called periodicity indices), an improved model was constructed which was capable of explaining about half (adjusted $R^2 = 0.5$) of the phytoplankton variance in the study area.

1. Introduction

River networks present dynamically changing physical gradients to all biota, including phytoplankton (Kingsford, 2000). From the headwater, the characteristics of streams may vary, from the heavily shaded streams of forested catchments to the deep channels of large autotrophic lowland rivers, where inorganic turbidity often restricts light availability (Dokulil, 2006; Istvánovics and Honti, 2012). The highest autotrophic productivity is to be expected in medium to large rivers, and in large floodplain rivers (Istvánovics et al., 2014).

With urbanization and rapid population growth, water bodies are being more and more threatened by over exploitation and pollution, rivers being one of the most endangered among them (Hering et al., 2006). Therefore, their monitoring is an absolute necessity if we are to be able to follow and predict negative changes/scenarios. The Water Framework Directive of the European Union (EC, 2000) stipulated the achievement of “good ecological status” in natural water bodies by 2015; this, in turn, requires the continuous development and cross-border intercalibration of monitoring networks in order to achieve a better understanding of rivers processes (Chapman et al., 2016).

One focal issue in this is eutrophication (Neal et al., 2008), which highlights the use of phytoplankton in the assessment of large rivers as a new and emerging task of the EU (Hering et al., 2010; Reyjol et al., 2014). Offering increasing development time, the lower stretches of a river may more easily become dominated by the planktonic element (Moss and Balls, 1989; Várbíró et al., 2007). This is manifested in a progressive increase in planktonic chlorophyll as one moves from the upper reaches to the middle-

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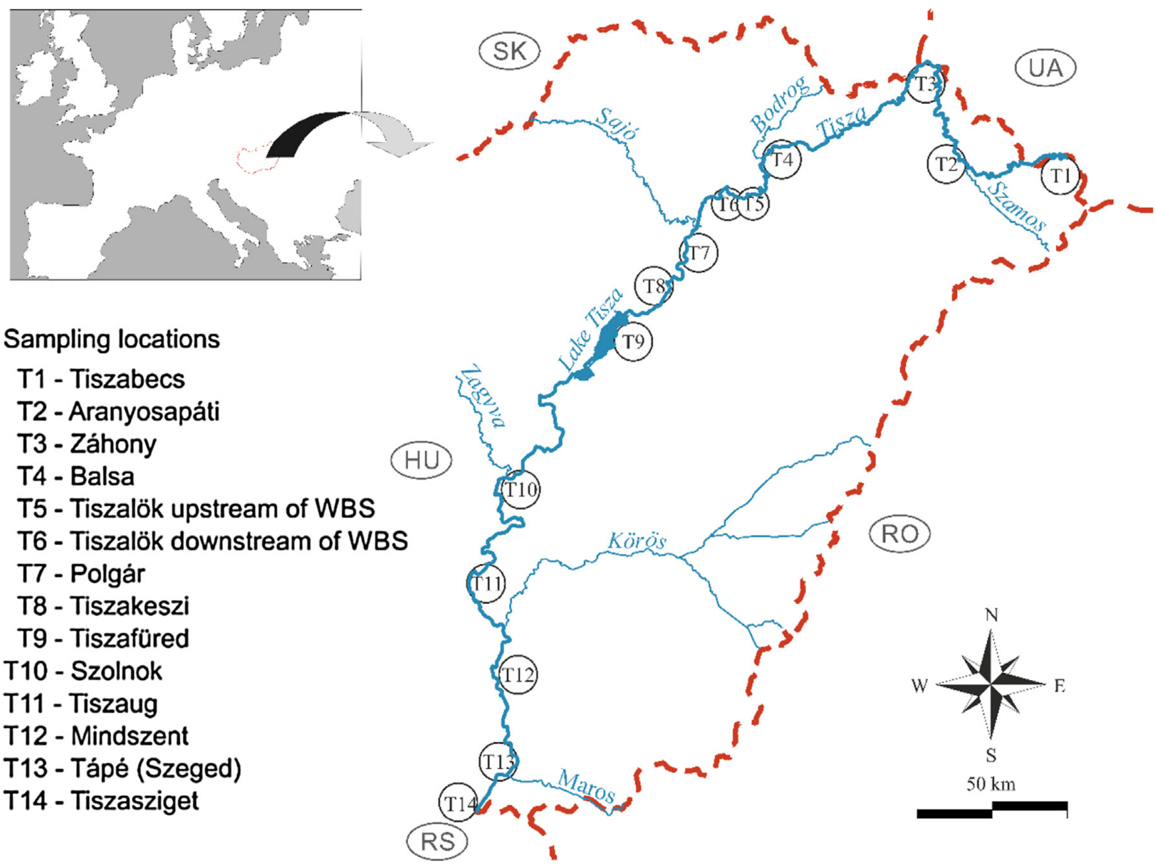

Fig. 1. Hungarian catchment of the River Tisza, with its sampling locations.

and lower sections of the river. Although, chlorophyll-a determination is neither a difficult nor expensive, long term data is generally only available from the 1990s in Eastern Europe, as only then was it first included as an important parameter in national water quality monitoring programs.

Phytoplankton play a vital role in fluvial ecosystems, especially in cases of changing climatic and environmental conditions (Villegas and de Giner, 1973). Also, due to their short life cycle, they serve as important indicators of water quality (Wu et al., 2014, 2012). Taken together, these points show why forecasting algal content is fundamental to the management of river systems (Jeong et al., 2008; Read et al., 2014). The need for the creation of a model of phytoplankton dynamics which is capable of approximating real life phenomena as closely as possible has already been formulated (Elliott et al., 2010), and successful models have been derived in the case of rivers (Jeong et al., 2001; Wu et al., 2014) and lakes, e.g. Lake Taihu (China; Huang et al., 2014, 2012). However, none of these models have taken the periodic behavior of various water quality parameters into account as a possible driving factor. Despite the fact that, as emphasized much earlier (Reynolds, 1984), the role of periodic cycles of phytoplankton has a crucial impact on population dynamics and shaping community structure.

The presence or absence of annual periodicity, as demonstrated in our research, is not as evident as it may seem at first. The complex nature of the interactions and the superimposed presence of anthropogenic-, as well as other natural processes may disturb the natural periodic behavior of different water systems (Kovács et al., 2010; Fehér et al., 2016). Therefore, both the periodic behavior of the main characteristics of water quality and the status of a river section play a determining role in whether the growth of riverine phytoplankton – a main characteristic of any given river section – occurs or not. In the upper section, the natural riverine phytoplankton consist of mainly tichoplatonic elements (Ruyter Van Steveninck et al., 1990; Descy, 1987) while in the lower-, true euplactonic cenrales diatoms tend to dominate the primary production pillar of riverine food webs (Descy et al., 2017). As primary producers, planktonic algae in aquatic environments have a determining role in shaping the composition of aquatic ecosystems through their production of organic carbon, oxygen, as well as providing a source of food for herbivorous grazers (Wehr and Descy, 1998). In addition, the disturbance in periodic behavior of phytoplankton in riverine systems triggers a chain reaction through the food web, as periodic behavior makes its effects felt through all sections of the riverine ecosystem and the ecosystem services provided (Daily, 1997). There is therefore, an obvious need to understand the driving constraints of phytoplankton dynamics in rivers.

Table 1
Groups of water quality/quantity variables assessed in the study.

Variables	Variable Groups
Runoff ($m^3 s^{-1}$)	
Dissolved oxygen (DO; $mg L^{-1}$)	
Biological oxygen demand (BOD-5; $mg L^{-1}$)	
Ca^{2+} ($mg L^{-1}$)	Ions
Mg^{2+} ($mg L^{-1}$)	
Na^{+} ($mg L^{-1}$)	
K^{+} ($mg L^{-1}$)	
Cl^{-} ($mg L^{-1}$)	
SO_4^{2-} ($mg L^{-1}$)	
HCO_3^{-} ($mg L^{-1}$)	
NH_4-N ($mg L^{-1}$)	Nutrients
NO_2-N ($mg L^{-1}$)	
NO_3-N ($mg L^{-1}$)	
PO_4-P ($\mu g L^{-1}$)	