Global changes incidence on phytoplankton, with special reference to cyanobacteria, in the R. Loire (France)

Impact des changements globaux sur le phytoplancton et les cyanobactéries de la Loire (France)

Maria Leitao[1]; András Abonyi[1,4]; Jean-Pierre Descy[2]; Anne Marie Lançon[1]; Camille Minaudo[3]; Florentina Moatar[3]

[1]Bi-Eau, Angers, France (leitao@bieau.fr); [2]Unité d'Océanographie Chimique, Université de Liège, Belgium; [3]E.A 6293 GéHCO - GéoHydrosytèmes COntinentaux, University of Tours, France; [4]Institute of Ecology and Botany, MTA Centre for Ecological Research, Vácrátót, Hungary

RÉSUMÉ

Le changement climatique, combiné à l'eutrophisation, risque d'affecter les conditions de croissance du phytoplancton dans les lacs et les rivières, avec un risque d'augmentation des nuisances associées aux blooms de cyanobactéries. Sur base de données physico-chimiques et de composition et de biomasse du phytoplancton recueillies au cours d'une vingtaine d'années dans la Loire, nous avons examiné les tendances à long terme en différents points du fleuve. Les résultats montrent une diminution progressive de la biomasse du phytoplancton dans la Loire, en parallèle avec une réduction des apports de nutriments. Au cours de la période d'étude (1991-2011), les cyanobactéries planctoniques n'ont pas excédé ~1% en moyenne de la biomasse du phytoplancton, même si elles ont présenté une augmentation amont-aval. Ces résultats suggèrent que le contrôle de l'eutrophisation – en même temps que des effets liés aux invasions biologiques - pourrait compenser les effets attendus du changement climatique dans les grands cours d'eau.

ABSTRACT

Climate change, combined to eutrophication, is expected to affect growth conditions of phytoplankton in lakes and rivers, with an increased risk of potentially harmful cyanobacterial blooms. Using physical and chemical data as well as data on phytoplankton composition and biomass collected over two decades in the Loire River, we examined long-term trends at different rivers sites. The results show a steady decrease of phytoplankton biomass in the R. Loire, in parallel with a reduction of nutrient inputs. During the study period (1991-2011), planktonic cyanobacteria did not exceed ~1% on average of phytoplankton biomass, even though they presented a downstream increase. These results suggest that eutrophication control – along with effects related to biological invasions - may mitigate the effects expected from climate change in large rivers.

MOTS CLÉS

Climate change, cyanobacteria, eutrophication, Loire, phytoplankton

1. CONTEXT AND AIMS

In the 1980s, the chlorophyll-*a* concentration of many European and North American rivers reached values well above the threshold for the eutrophic class (30 µg/l; Dodds and Smith, 2016), and with great interannual variability. At this time, the Loire River in France was mentioned by several authors (e.g. Crouzet, 1983) as the most eutrophic European river, where chlorophyll-*a* could exceed 300 µg/l in the Middle Loire reach. Since then, the Loire River has undergone many changes: i) alteration of hydrological and thermal conditions in relation to climate change, ii) change in nutrient loads and elemental ratios due to phosphorus load mitigation (Minaudo et al., 2014), iii) decrease of suspended sediment load during summer and iv) invasion by exotic macroinvertebrates including benthic filter-feeders (i.e. *Corbicula;* Floury et al., 2013) that may have impacted phytoplankton. Moreover, there has been widespread concern that climate change, combined with eutrophication, will result in increasing the risk of potentially toxic cyanobacterial blooms in fresh waters, particularly in lakes where extended periods of stratification and longer residence time may contribute to increasing the occurrence of planktonic cyanobacteria blooms.

In this context, we investigated long-term changes of phytoplankton as driven by multiple factors in the Loire River with a focus on biomass changes along the 1 000 Km of the water course and on the changes in phytoplankton that occurred over a 20 year period. We expected that:

(1) phytoplankton biomass (specially cyanobacteria, including potentially toxic taxa) would be higher in low-flow years than in high-flow years;

(2) total and cyanobacterial biomass would exhibit a downstream increase, as a result of retention time increase;

(3) cyanobacteria originating from upstream eutrophic reservoirs would decrease as going downstream;

(4) decrease of P availability due to improved wastewater treatment would, in the long term, reduce the likelihood of large phytoplankton blooms.

2 METHODS

For phytoplankton, 6 stations along the Loire were regularly sampled from 1991 and 2011, during a monitoring conducted by the Loire-Bretagne Water Agency. The upper station (Malvalette) was 150 km from the source, and the most downstream was at km 885 (Montjean). Phytoplankton was identified and then counted according to Utermöhl method; biomass was calculated using biovolumes and subsequent conversion to carbon (µg C L^{-1}).

Water quality concentrations (nitrate, total and dissolved reactive phosphorus, suspended sediment, chlorophyll-*a*) were originated from the monthly monitoring. River flow data on a daily basis were taken from the national “Banque Hydro” database. Daily water temperature averages originated from the company “Electricité de France” at three stations located upstream three nuclear power plants.

For each site, long-time trends on hydrological, physical and chemical conditions were calculated on seasonal metrics such as: annual averages from April to October of daily discharge, daily water temperature, monthly water quality and monthly phytoplankton biomass (cyanobacteria and total biomass were considered). Additionally, the number of days for which daily discharge remained under the 10th percentile of long-term time series. The relationship between phytoplankton community composition and local environmental predictors was assessed by constrained analysis of principal coordinates. First we calculated a distance matrix from the Hellinger-transformed compositional data (Bray Curtis dissimilarity), and subjected its PCoA ordination scores to a distance-based redundancy analysis (function capscale in vegan R package).

3 RESULTS AND CONCLUSION

The results show that phytoplankton biomass has dramatically decreased in the River Loire (fig. 1) as well as in its main tributaries, suggesting a positive result of implementation of measures to control eutrophication. We did not detect any significant increase of planktonic cyanobacteria, which most of the time represented on average 1.05 %. of total phytoplankton biomass (fig. 2).

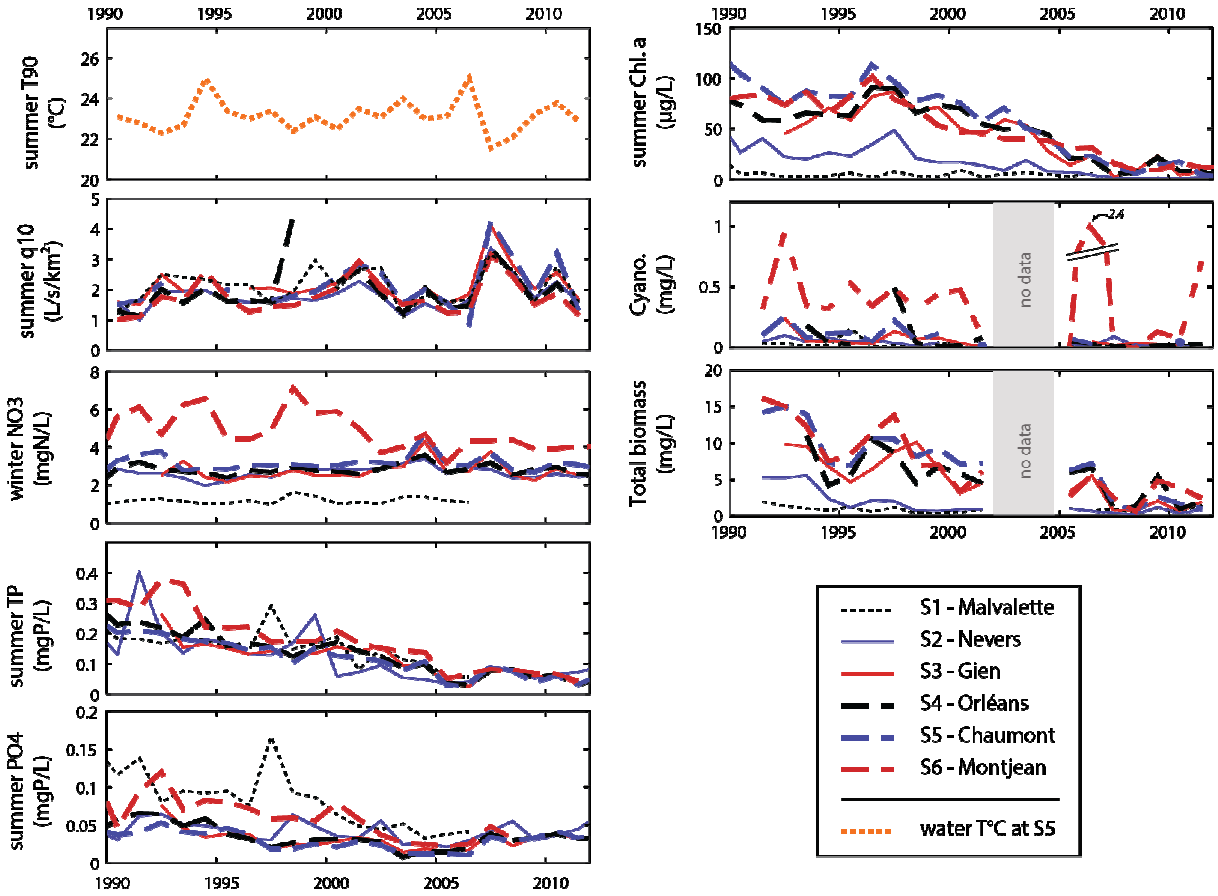
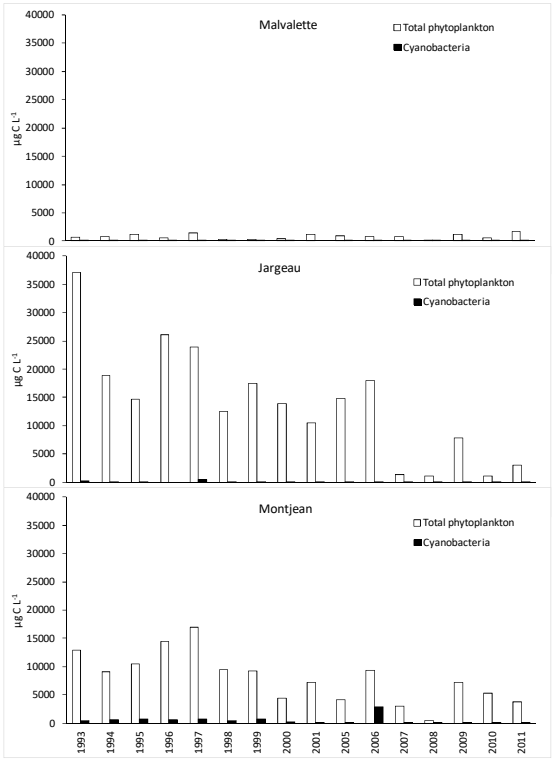


Figure 1. Trends on physical and chemical conditions (left column) and on biomass concentrations (right).



Moreover, the substantial reduction of P inputs to the river network may have induced significant P-limitation of phytoplankton growth, affecting cell size distribution and contributing to the reduction of the occurrence of large phytoplankton blooms in the Loire River. This suggests that eutrophication control may mitigate the effects of hydrological and temperature changes expected from climate change in large lowland rivers, and prevent the risk associated with harmful cyanobacterial blooms. To some extent, the colonization of the river network by exotic benthic filter-feeders may have contributed to the changes observed in phytoplankton biomass and composition, and to other ecosystem changes such as improvement of water transparency and aquatic macrophytes development. These, however, remain to be investigated.

Figure 2. Average annual phytoplankton biomass and contribution of cyanobacteria along the Loire River from 1993 to 2011.

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