Longitudinal phytoplankton development in two large rivers

Développement longitudinal du phytoplancton dans deux grands fleuves

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RÉSUMÉ

La question centrale de cette étude concerne les différences dans le développement longitudinal du phytoplancton dans deux grands fleuves, le Rhin et l'Elbe. Pour étudier le développement du plancton, les processus d'accroissement et de perte, ainsi que les paramètres physico-chimiques, quatre campagnes longitudinales ont été réalisées en aval des fleuves entre 2009 et 2011. Par ailleurs, l'effet des communautés d'invertébrés benthiques sur le développement du phytoplancton a été étudié lors d'une autre campagne. Pendant les deux campagnes, la concentration maximale de chlorophylle dépassait 120 µg L-1 dans l'Elbe. À l'inverse, lors des campagnes concernant le Rhin, les concentrations maximales de chlorophylle étaient très basses en 2010 (< 5 µg L-1), alors que les concentrations atteignaient 244 µg L-1 en 2011. Ces concentrations exceptionnellement hautes ont été trouvées malgré une grande abondance de bivalves benthiques et ont coïncidé avec une période de débits bas. Cette observation ne correspond pas à la tendance d'abaissement de la biomasse du phytoplancton, qui a été observée à long terme et qui dépasse toutes les concentrations de chlorophylle mesurées dans le Rhin au cours des trois dernières décennies.

ABSTRACT

The central question of this study concerns differences in the longitudinal phytoplankton development in the two large rivers Rhine and Elbe. To investigate the development of plankton, its growth and loss processes as well as physical and chemical parameters, four Lagrangian sampling campaigns were performed along the two rivers between 2009 and 2011. In a separate measuring campaign, the impact of benthic filter feeders on the phytoplankton development was examined. In both sampling campaigns, maximum chlorophyll concentrations in the Elbe exceeded 120 µg L^{-1}. By contrast, chlorophyll concentrations were very low in the Rhine during the sampling campaign in 2010 (< 5 µg L^{-1}), but reached up to 244 µg L^{-1} in 2011. These unusually high chlorophyll concentrations were found despite high bivalve abundances in the Rhine and coincided with a low discharge event. This observation contrasts with the decreasing long-term trend in phytoplankton biomass and exceeds the chlorophyll values measured in the Rhine during the last three decades.

KEYWORDS

Bivalves, Lagrangian approach, large rivers, phytoplankton, plankton dynamics

1 INTRODUCTION

In large rivers, different factors are relevant for the development of plankton. The most important factors include flow regulation by impoundments, nutrient conditions, biotic factors, light conditions and water residence time. As eutrophication can still be considered a threat to aquatic ecosystems including rivers, it is important to understand the mechanisms governing the development of plankton in order to preserve the health of the ecosystem and ultimately guarantee the sustainable development of riverine and coastal water resources. The present study reveals differences between the two large rivers Rhine and Elbe especially concerning the net-effects along the free-flowing river stretches, including tributary impacts, river-internal processes, as well as potential grazing impacts from benthic filter-feeders. For this purpose, a combination of Lagrangian sampling campaigns and an inventory survey, encompassing a quantitative sampling of benthic bivalves to assess the grazing potential, was realized. The long-term development of phytoplankton since the mid-1990s elucidated a decreasing trend of phytoplankton biomass in the Rhine (Friedrich and Pohlmann 2009; Hardenbicker et al. 2014) and different explanations were provided ranging from potential grazing pressures, nutrient limitation to light limitation. Our main hypothesis is that the low present phytoplankton densities in the Rhine are a consequence of high grazing pressures from the invasive bivalves in the Rhine.

2 METHODS

The canalized and free-flowing part of the Rhine from the Swiss-German border (Rhine-km 170, Basel) to the Dutch-German border (Rhine-km 865, Bimmen) was examined in autumn 2010 (September 21st – September 29th) and spring 2011 (May 17th – May 27th) by means of a Lagrangian sampling campaign. Along the free-flowing German section of the Elbe from the Czech-German border (Elbe-km 0, Schmilka) to the tidal weir close to Hamburg (Elbe-km 582, Geesthacht), two Lagrangian sampling campaigns were performed in autumn 2009 (September 4th – September 13th) and summer 2011 (August 8th – August 15th). For 2010 and 2011, an inventory control sampling of the bivalves *Corbicula* spp. (*Corbicula fluminea* and *Corbicula fluminalis*) and *Dreissena* spp. (*Dreissena polymorpha* and *Dreissena rostriformis*) was performed along the Rhine and the Elbe using ship-based large grab samplers.

3 RESULTS AND DISCUSSION

Pronounced differences were found in the longitudinal chlorophyll development in both rivers. While in the Rhine in 2010 chlorophyll values were very low (below 5 µg L^{-1}, intermediate discharge conditions, flow time = 8 days) they increased up to 244 µg L^{-1} at the most downstream station at Bimmen, Rhine-km 865, in May 2011 (Fig. 1a,b). In the Rhine in May 2011, there was a pronounced low discharge event (flow time = 10 days), and light and nutrient conditions were only limiting in the most downstream river reaches during this extreme event. Surprisingly, chlorophyll values exceeded all values measured during the last three decades (max. 180 µg L^{-1}, 1979 – 2009 at Bimmen, Friedrich and Pohlmann 2009). By contrast, chlorophyll values exceeded 120 µg L^{-1} in the Elbe during both, a high (2011, flow time = 6 days) and a lower discharge event (2009, flow time = 7.5 days) (Fig. 1c,d). Low zooplankton abundances detected in the Rhine agreed with the general finding of a low biovolume of plankton components in the Rhine (Scherwass et al. 2010). Likewise in the Elbe, comparably low zooplankton abundances suggested a minor grazing pressure during our sampling campaigns. Tributaries had contrasting impacts on the plankton development in both rivers: while they supplied phytoplankton concentrations in the Rhine, they predominantly diluted the concentrations in the Elbe. This observation complies with the finding that the input from tributaries is rather important (Scherwass et al. 2010). The low chlorophyll values found in the Rhine in 2011 could be due to a high density of benthic filter feeders possibly exerting a strong grazing impact. In the Rhine, very high bivalve abundances of up to 1,248 ind. m^{-2} for *Corbicula* spp. (*Corbicula fluminea*, *Corbicula fluminalis*) and of up to 3,184 ind. m^{-2} for *Dreissena* spp. (*Dreissena polymorpha*, *Dreissena rostriformis*) prevailed. By contrast, bivalve abundances reached only 70 ind. m^{-2} for *Corbicula* spp. and stayed predominantly below 500 ind. m^{-2} for *Dreissena* spp. in the Elbe.

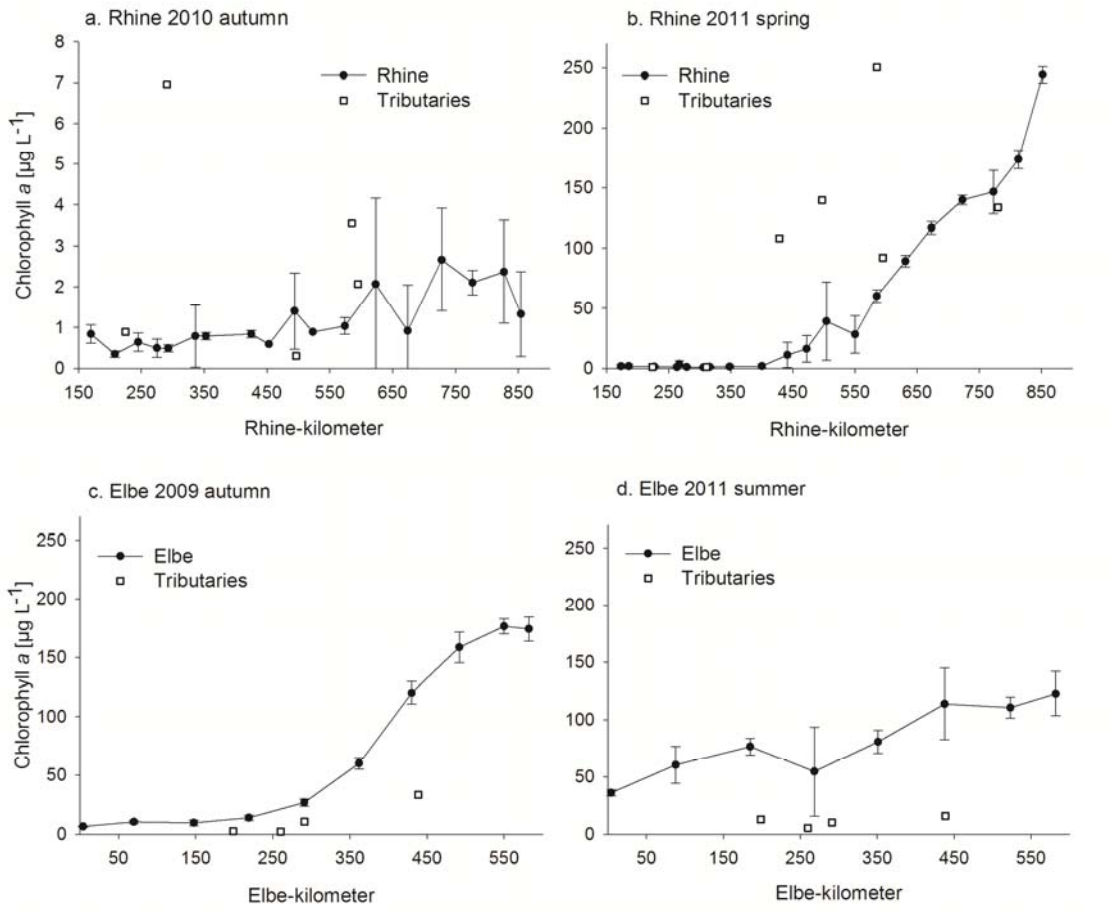

Fig. 1: Chlorophyll development during longitudinal transport in the Rhine (a, b) and in the Elbe (c, d): black dots present values of the main river (mean of the right, middle and left side of the river, ± standard deviation), empty symbols present the tributary concentrations (a: Rest-Rhine km 225, Rest-Rhine km 291, Main, Lahn, Moselle; b: Rest-Rhine km 225, Ill, Neckar, Main, Lahn, Moselle, Ruhr, c and d: Schwarze Elster, Mulde, Saale, Havel).

4 CONCLUSIONS

In both rivers, high chlorophyll concentrations in the middle and lower river reaches developed independently of the start values in the upper reaches as a result of growth and loss processes during downstream transport. In the Rhine, a low discharge event in spring led to pronounced phytoplankton growth compensating possible losses to the benthos. This event shows that the potential to develop a high phytoplankton biomass is given, even though it is not realized under mean discharge conditions.

LIST OF REFERENCES

Friedrich, G. and Pohlmann, M. (2009). Long-term plankton studies at the lower Rhine/Germany. Limnologica 39(1), 14-39. doi:10.1016/j.limno.2008.03.006.

Hardenbicker, P., Rolinski, S., Weitere, M. and Fischer, H. (2014). Contrasting shifts and long-term trends in phytoplankton dynamics in two large rivers. Int. Rev. Hydrobiol. 99, 287-299. doi:10.1002/iroh.201301680.

Scherwass, A., Bergfeld, T., Schoel, A., Weitere M. and Arndt, H. (2010). Changes in the plankton community along the length of the River Rhine: Lagrangian sampling during a spring situation. J. Plankton Res. 32(4), 491-502. doi:10.1093/plankt/fbp149.