Influence of network connectivity on benthic and pelagic algal communities in a Danube floodplain system (Austria)

Influence de la connectivité du réseau sur les communautés d'algues benthiques et pélagiques dans un système de plaine inondable du Danube (Autriche)

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RÉSUMÉ

Cette étude examine l'influence de la connectivité des réseaux sur la composition et la fonction des communautés d'algues benthiques et pélagiques dans le parc national du Danube, en Autriche. En examinant les paramètres spatiaux (paramètres statiques et réels du réseau) et environnementaux, nous cherchons à comprendre comment ces facteurs affectent la distribution et la fonction des algues. Les indices de connectivité, y compris la centralité harmonique et la centralité d'interdépendance, ont été calculés pour évaluer les paramètres statiques et dynamiques du réseau. Les résultats préliminaires indiquent que les paramètres de réseau statiques décrivent mieux les algues benthiques en plus de la composition des sédiments et de la couverture des macrophytes, tandis que les paramètres réels sont plus influents pour les communautés pélagiques. Nos résultats soulignent l'importance de la connectivité des réseaux dans la formation des communautés d'algues et mettent en évidence la nécessité de stratégies de conservation qui maintiennent ou restaurent la connectivité des réseaux dans les systèmes de plaines d'inondation. Cette recherche contribue à une meilleure compréhension de la dynamique écologique au sein des paysages fluviaux et informe sur les pratiques de gestion efficaces.

ABSTRACT

This study investigates the influence of network connectivity on the community composition and function of benthic and pelagic algae in the Danube National Park, Austria. By examining both spatial (static and actual network parameters) and environmental parameters, we aim to understand how these factors influence algal distribution and function. Connectivity indices, including harmonic centrality and betweenness centrality, were calculated to assess static and dynamic network parameters. Preliminary results indicate that static network parameters better describe benthic algae in addition to sediment composition and macrophyte cover, while current parameters are more influential for pelagic communities. Our findings highlight the importance of network connectivity in shaping algal communities and underline the need for conservation strategies that maintain or restore network connectivity in floodplain systems. This research contributes to a deeper understanding of the ecological dynamics within riverine landscapes and informs effective management practices.

KEYWORDS

environmental parameters, floodplain, network Connectivity, phytobenthos, phytoplankton

connectivité du réseau, paramètres environnementaux, phytobenthos, phytoplancton, plaine d'inondation

EXTENDED ABSTRACT

1.1 Introduction

Large rivers are heavily influenced by a range of human activities, including flood control, land use changes, navigation, hydropower, urban development, and agriculture. These interventions often result in a reduced or severely limited hydrologic connectivity between rivers and their adjacent floodplains. In addition, network connectivity between different riparian zones or parts of the floodplain may also be significantly affected. This loss of connectivity poses a serious threat to floodplains, which are among the most diverse and productive ecosystems on Earth (Tockner & Stanford, 2002). The high variability of hydrological and morphological water bodies within floodplains, such as oxbows, lakes, lagoons, streams, and backwaters (Mihaljević et al., 2015), is essential for maintaining biodiversity and ecosystem services. However, this diversity is increasingly under threat. To understand and mitigate these changes, bioindicators such as benthic and pelagic algae are crucial. These organisms, with their short life cycles and rapid responses to environmental changes, are particularly effective for studying changes in connectivity and their effects on floodplain systems (Schagerl et al., 2009; Pfeiffer et al., 2015). While considerable research has been conducted on longitudinal and lateral connectivity in river systems, network connectivity—a concept adapted from landscape conservation planning (Saura & Pascual-Hortal, 2007)—remains relatively understudied in the context of floodplains. Network connectivity is closely linked to hydrological variability, which influences the chemical and physical conditions in floodplain systems and, consequently, affects the algal communities inhabiting these habitats (Mihaljević et al., 2015).

Variations in connectivity are expected to affect the community composition of benthic and pelagic algae, that function as metacommunities (Leibold et al., 2004; Altermatt, 2013). It is hypothesised that sites that are more closely connected, either to each other or to the main river channel, will show greater similarity in algal community composition and function along the connectivity gradient. Thus, the study of connectivity gradients provides valuable insights into the ecological functioning and conservation of floodplain ecosystems.

In this study, we address two research questions. First, how do spatial and environmental parameters relate to the distribution of benthic and pelagic algae in terms of biomass and pigment composition? We hypothesize that pelagic algae will be more strongly influenced by spatial parameters, whereas benthic algae will be more influenced by environmental parameters.

Second, we investigate whether static or dynamic network parameters increase the proportion of spatial factors in a variance partitioning model. We hypothesize, that the pigment composition and functional traits of benthic algae are better described by static network parameters, representing an average hydrological situation. In contrast, the pelagic community is more influenced by actual network parameters, reflecting the temporal variability of connectivity and flow dynamics.

1.2 Methods

Field sampling was carried out six times in 2022 and 2023 during spring and summer, under conditions below and around the mean flow (MQ). Ten study sites were selected within the Danube National Park (Austria), specifically in the Lobau and on the Danube Island. These sites represented a gradient of connectivity, ranging from highly connected to isolated. The sites varied in substrate type, being either gravel dominated or psammopelal dominated. In addition, each site was characterized based on its environmental conditions, including depth, flow velocity, turbidity, canopy cover, macrophyte cover, and light availability. This comprehensive approach allowed for a detailed assessment of both connectivity and site-specific ecological conditions.

The physico-chemical properties of the water and sediment were assessed at each sampling site. **In the field**, conductivity and pH were measured using the HQ Series Multi pH probe (Hach Lange). **In the laboratory**, three water samples from each site were analyzed for dissolved organic carbon (DOC), dissolved organic nitrogen (DON), ammonium (NH_4^+), nitrate (NO_3^-), and soluble reactive phosphorus (SRP). Sediment analysis included ten samples per site, focusing on the concentrations of SRP, NO_3^-, NH_4^+, carbon (C), nitrogen (N), and phosphorus (P).

For biological analyses, **ten phytobenthos samples** and **three phytoplankton samples** were collected per site to investigate structural variables, such as the percent of organic matter, ash-free dry mass (AFDM), chlorophyll-a (Chl-a), pigments, and elemental compositions (C, N, P), and stoichiometric ratios (C:N, C:P, and N:P). In addition to structural variables, functional variables were also evaluated. For phytobenthos, **ten samples per site** were analyzed in the field using the Diving PAM II (Walz), measuring parameters such as maximum electron transport rate (ETRmax), yield, and photosynthesis indices. Similarly, for phytoplankton, **five samples per site** were analysed in the laboratory using the Phyto PAM (Walz). This thorough analysis provided insights into both the structural and functional dynamics of the phytobenthos and phytoplankton communities across the study sites.

Connectivity indices were calculated in two ways: **static**, representing the whole network, and **actual**, reflecting the hydrological connectivity with the Danube during the sampling periods. The indices used included harmonic centrality (Rochat, 2009), betweenness centrality (Barrat et al., 2004), and the probability of connectivity index (Saura & Pascual-Hortal, 2007).

1.3 Preliminary results

For phytoplankton, network parameters, in particular directed flow, play a more important role in shaping phytoplankton communities in spring, but become less influential in summer as other factors take precedence. Key environmental factors, such as macrophyte cover and canopy cover, also have a significant effect on phytoplankton communities. Overall, the actual network parameters proved to be good descriptors of phytoplankton distribution and structure.

In the case of phytobenthos, there is a strong interaction between environmental and spatial parameters. Sediment composition and macrophyte cover are particularly important environmental factors influencing benthic communities. Furthermore, static network parameters are effective descriptors of the distribution and structure of benthic algae.

LIST OF REFERENCES

1 Altermatt, F. (2012). Metacommunity dynamics. In Gibson, D. (Ed.), Oxford Bibliographies Online: Ecology. Oxford University Press, New York. Retrieved from http://www.oxfordbibliographies.com/view/document/obo-9780199830060/obo-9780199830060-0021.xml. Accessed 30 January 2022.

2 Altermatt, F. (2013). Diversity in riverine metacommunities: A network perspective. Aquatic Ecology, 47(3), 365–377. https://doi.org/10.1007/s10452-013-9450-3

3 Barrat, A., Barthélemy, M., Pastor-Satorras, R., & Vespignani, A. (2004). The architecture of complex weighted networks. Proceedings of the National Academy of Sciences (PNAS), 101(11), 3747–3752. https://doi.org/10.1073/pnas.0400087101

4 European Commission (2000). Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for community action in the field of water policy. Retrieved from https://www.bmu.de/fileadmin/bmuimport/files/pdfs/allgemein/application/pdf/water_framework_directive.pdf. Accessed 6 December 2021.

5 Holyoak, M., Leibold, M. A., & Holt, R. D. (Eds.). (2005). Metacommunities: Spatial dynamics and ecological communities. The University of Chicago Press, Chicago.

6 Leibold, M. A., Holyoak, M., Mouquet, N., Amarasekare, P., Chase, J. M., Hoopes, M. F., Holt, R. D., Shurin, J. B., Law, R., Tilman, D., Loreau, M., & Gonzalez, A. (2004). The metacommunity concept: A framework for multi-scale community ecology. Ecology Letters, 7(7), 601–613. https://doi.org/10.1111/j.1461-0248.2004.00608.x

7 Mihaljević, M., Stević, F., Špoljarić, D., & Pfeiffer, T. Ž. (2015). Spatial pattern of phytoplankton based on the morphology-based functional approach along a river-floodplain gradient. River Research and Applications, 31(2), 228–238. https://doi.org/10.1002/rra.2739

8 Pfeiffer, T. Ž., Mihaljević, M., Špoljarić, D., Stević, F., & Plenković-Moraj, A. (2015). The disturbance-driven changes of periphytic algal communities in a Danubian floodplain lake. Knowledge and Management of Aquatic Ecosystems, 416, 2. https://doi.org/10.1051/kmae/2014038

9 Rochat, Y. (2009). Closeness centrality extended to unconnected graphs: The harmonic centrality index.

10 Saura, S., & Pascual-Hortal, L. (2007). A new habitat availability index to integrate connectivity in landscape conservation planning: Comparison with existing indices and application to a case study. Landscape and Urban Planning, 83(2), 91–103. https://doi.org/10.1016/j.landurbplan.2007.03.005

11 Schagerl, M., Drozdowski, I., Angeler, D. G., Hein, T., & Preiner, S. (2009). Water age—a major factor controlling phytoplankton community structure in a reconnected dynamic floodplain (Danube, Regelsbrunn, Austria). Journal of Limnology, 68(2), 274–287. https://doi.org/10.4081/jlimnol.2009.274

12 Tockner, K., & Stanford, J. A. (2002). Riverine floodplains: Present state and future trends. Environmental Conservation, 29(3), 308–330. https://doi.org/10.1017/S037689290200022X

13 Vannote, R. L., Minshall, G. W., Cummins, K. W., Sedell, J. R., & Cushing, C. E. (1980). The River Continuum Concept. Canadian Journal of Fisheries and Aquatic Sciences, 37(1), 130–137. https://doi.org/10.1139/f80-017

14 Ward, J. V. (1989). The four-dimensional nature of lotic ecosystems. Journal of the North American Benthological Society, 8(1), 2–8. https://doi.org/10.2307/1467397