Exploring damming and restoration long-term effects on side channel biodiversity using macrofossils in river sediment cores

Investiguer les effets à long terme de la construction d'un barrage et de la restauration sur la biodiversité dans des chenaux secondaires à partir des macro-restes issus de carottes de sédiments fluviatiles.

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RÉSUMÉ

Cette recherche vise à reconstruire les changements de biodiversité à long terme (post-1950) dans des chenaux secondaires en analysant les macro-restes (végétaux, animaux ou abiotiques < 5 mm) accumulés dans les sédiments fluviatiles. Cette approche s'appuie sur des carottes fluviales datées à l'aide de radionucléides le long du Rhône. Les macro-restes, notamment les taxons forestiers et aquatiques, permettent de reconstruire l'histoire des habitats et de la biodiversité depuis 1950, avec trois phases hydro-écologiques majeures, en lien avec l'aménagement et la gestion du fleuve. Une première phase, avant la construction du barrage, montre une ripisylve diversifiée, indiquée par la présence d'écailles d'aulne noir, de graines d'arbousier et de fragments de bois. La seconde phase, dans les années 1980-1990, voit une transition vers des écosystèmes terrestres suite à la mise en dérivation du tronçon étudié, et l'expansion de plantes nitrophiles. Puis, après 2000, les macro-restes révèlent l'établissement de nouvelles plantes aquatiques et de zones humides, faisant suite aux actions de restauration. L'étude de ces bioindicateurs offre un complément important par rapport aux données sédimentologiques et aux inventaires floristiques ponctuels pour analyser l'évolution des habitats ripariens suite aux aménagements du fleuve et aux actions de restauration. Cette approche peut aider à définir des conditions de référence et peut être un outil améliorant le suivi des zones humides alluviales, avec une vision rétrospective.

ABSTRACT

This research aims at reconstructing long-term (post-1950) biodiversity changes on side channels by analysing macrofossils (plant, animal or abiotic remains < 5 mm) accumulated in sediment deposits. This approach relies on river cores dated by radionuclide along the Rhone River. Macrofossils, especially forest and aquatic taxa, provide a history of habitats and biodiversity since 1950, revealing three main hydro-ecological phases linked to river developments and management. The first phase, before dam construction, highlights a diversified riverine forest marked by black alder scales, strawberry seeds and wood fragments. The second phase, in the 1980s-1990s, indicates a transition to terrestrial ecosystems due to water diversion, and the expansion of nitrophilous plants. Then, after 2000, macrofossil data reveal new wetland and aquatic plants after channel restoration. The study of these bioindicators provide a valuable complement to sedimentological data and to plant inventories in order to analyse the evolution of riparian habitats following developments or restoration actions. This approach can help to define reference conditions and can be a tool improving the monitoring of alluvial wetlands, with a retrospective view.

KEYWORDS (5 keywords, in alphabetical order, separated by a comma)

Secondary channels, plant macrofossils, iron slags, Anthropocene, river management

Chenaux secondaires, macro-restes botaniques, scories, Anthropocène, gestion des cours d'eau

EXTENDED ABSTRACT

During the Anthropocene, river ecosystems have been significantly impacted by multiple human activities (e.g. water control and navigation facilities, hydroelectrical power plants, agricultural needs), leading to hydro-sedimentary changes, alterations in vegetation, and ecosystem degradation (Kelly et al., 2018). Side channels, which are non-perennial habitats located along the main river branches, experience various stages of hydro-ecological evolution, often resulting in reduced connectivity with main rivers (Bouska et al., 2023). These changes can lead to the rapid terrestrialization of side channels, those water bodies become isolated and accumulate more or less contaminated sediments (Dépret et al., 2017; Vauclin et al., 2021). Based on the Water Framework Directive (WFD/DCE 2000), recent efforts have focused on restoring these side channels to enhance biodiversity and ecological continuity in Europe. However, past references on the biodiversity of the ecosystems to be restored and their evolution over time are often lacking.

To better understand long-term biodiversity changes in these habitats, our research will focus on the analyse of macrofossils from sediment cores extracted from two side channels of the Rhône River. We aim to assess the history of riparian habitats and biodiversity since the 1950s by analysing macrofossil indicators across sites and by reconstructing ecosystem trajectories related to engineering or restoration actions. This approach, inspired by palaeoecology, seeks to provide insights into the ecological impacts and changes caused by past human interventions in order to advise future management strategies.

MATERIAL AND METHODS

The study area is a 12 km-long stretch of the Rhône River (France), namely the Péage-de-Roussillon (PDR) sector (Fig. 1). This area undergone significant engineering modifications since the late 19th century (Seignemartin et al., 2023). Initially, it was straightened with dyke-fields in order to facilitate navigation. Then, a dam was built in 1977 in order to product hydroelectricity. It drastically reduced the water discharge in the PDR sector from more than 1,000 m^3/s to less around 20-10 m^3/s on average. These changes led to dewatering and sediment accumulation in the old river margins and in side channels (Seignemartin et al., 2023). Both environments have been colonized by pioneering species (Janssen et al., 2021). The area is a part of the "Ile de Platière" Nature Reserve since 1986, and various restoration efforts, including increasing the minimum instream flow and dredging and/or reconnecting some of the side channels, have been undertaken to improve hydro-sedimentary and ecological conditions.

Several fluvial sediment cores have been extracted from two side channels, called Limony and Ilon, located on either side of the Old Rhône River, 50 km south of Lyon (Fig. 1). It has been shown that these sequences have recorded sediment since the 1950s and 1970s respectively, based on radionuclide and pollutant organic persistent trends (Vauclin et al., 2021; Fig. 1).

In total, 52 samples were extracted on the cores at a resolution comprised 2.5 to 4 cm, meaning that a sample was analysed each 2 years according to the chronological models. Macroremains >400 µm were recovered after the sieving of the samples under a gentle jet of water. Plant and animal macrofossils were sorted and identified based on the regional data and on photographic atlases (e.g. Birks, 2017). In addition, quartz grains, macrocharcoals and iron slags were also identified according to their texture and aspect (Dendievel et al., 2024). After standardisation, macrofossil data were statistically treated by multivariate regression trees in order to highlight the succession of taxa groups over time.

MAIN RESULTS AND DISCUSSION

The analysis of macrofossils preserved in sediment cores in two different sites allowed to identify three major phases (Dendievel et al., 2024). The initial phase reveals diverse local riparian taxa according to the finding of black alder scales, strawberry seeds and wood fragments, among other. Numerous fragmented macrocharcoals and industrial microwaste, such as iron slags, were also found. These materials reflect the composition of the sediment transported by the river before the construction of the Saint-Pierre-de-Boeuf dam in 1977. Strong correlations were observed between iron slags, macrocharcoals, and magnetic susceptibility, suggesting a shared accumulation process likely linked to industrial releases coming from upstream. The Gier River is suspected as a major source for these remains (Dendievel et al., 2024).

Following the bypassing of the river in 1977, the biodiversity recorded in the macrofossil record diminished significantly, despite an increase in total organic carbon. The decrease in biodiversity seems to be attributable to the dewatering, which impacted the wetlands, no longer sufficiently supplied with water (Fig. 1). Thus, nettle seeds were dominant, likely due to reduced water levels after the damming and changes in nitrogen dynamics. The ecosystem shifts from a lotic to a more terrestrial environment due a quick terrestrialization. The decrease of the median grain size and the lack of iron slags and macrocharcoals, also demonstrates the gradual disconnection from the Rhône River inputs.

In the most recent sediment accumulation phases, the cores showed evidence of new lentic conditions, marked by an increase in wetland and aquatic taxa. The shift to these conditions began around 1999–2000, aligning with increased river discharge, and was further consolidated by the 2014 minimum instream flow initiative. Local events, such as the clearing of poplar stands, also contributed to shifts in macrofossil composition.

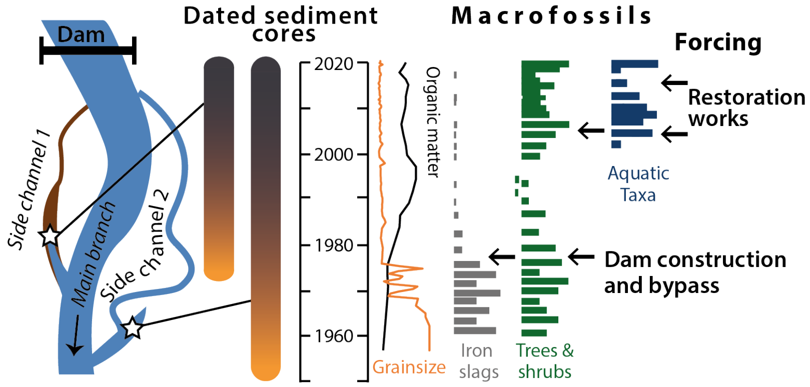

Fig. 1 – Graphical abstract of this research (based on Dendievel et al., 2024)

CONCLUSION

This research highlights the challenge of analysing and interpreting macrofossil remains preserved in well dated post-1950 sediment cores from river side channels. This successful attempt shows reliable and robust results that can be linked to engineering and managing actions. The main finding was to reconstruct a coherent history of species habitats and biodiversity over time in the studied sites. More specifically, we have demonstrated simultaneous phases of riparian dynamics, followed by a synchronous landing of the sites at the time of the diversion, before a renewal of wetland and aquatic taxa during the most recent years. The study demonstrates that macrofossil data can provide crucial feedback on development and restoration impacts. This approach can also help to define reference conditions and to supplement the monitoring of ecological changes over decades. In addition to macrofossil analysis, our future plans are to also perform palynological and eDNA analyses in the same sediment cores for a more comprehensive understanding of ecosystem changes over time.

LIST OF REFERENCES

Birks, H.H., 2017. Plant Macrofossil Introduction. *Reference Module in Earth Systems and Environmental Sciences* B978-0-12-409548-9.10499–3. https://doi.org/10.1016/B978-0-12-409548-9.10499-3

Bouska, K.L., Sobotka, M., Slack, T., Theel, H., 2023. Understanding ecological response to physical characteristics in side channels of a large floodplain-river ecosystem. *STOTEN* 871, 162132. https://doi.org/10.1016/j.scitotenv.2023.162132

Dendievel, A.-M., Riquier, J., Mourier, B., Winiarski, T., 2024. Tracking the effects of dam construction and restoration on side channel biodiversity using macrofossils in river sediment records. *STOTEN* 177246. https://doi.org/10.1016/j.scitotenv.2024.177246

Dépret, T., Riquier, J., Piégay, H., 2017. Evolution of abandoned channels: Insights on controlling factors in a multi-pressure river system. Geomorphology, Anthropogenic Sedimentation 294, 99–118. https://doi.org/10.1016/j.geomorph.2017.01.036

Janssen, P., Evette, A., Piégay, H., Pont, B., 2021. Rétablir la connexion latérale des rivières en démantelant d'anciens ouvrages de protection : premiers résultats d'une étude pluriannuelle sur le Rhône. *Sciences Eaux & Territoires* HS 81, 2–8. https://doi.org/10.14758/SET-REVUE.2021.HS.10

Kelly, J.R., Scarpino, P., Berry, H., Syvitski, J., Meybeck, M., 2018. *Rivers of the Anthropocene*. University of California Press, Oakland (USA), p. 212. https://doi.org/10.1525/luminos.43.

Seignemartin, G., Mourier, B., Riquier, J., Winiarski, T., Piégay, H., 2023. Dike fields as drivers and witnesses of twentieth-century hydrosedimentary changes in a highly engineered river (Rhône River, France). *Geomorphology* 431, 108689. https://doi.org/10.1016/j.geomorph.2023.108689

Vauclin, S., Mourier, B., Dendievel, A.-M., Noclin, N., Piégay, H., Marchand, P., Vénisseau, A., de Vismes, A., Lefèvre, I., Winiarski, T., 2021. Depositional environments and historical contamination as a framework to reconstruct fluvial sedimentary evolution. *STOTEN* 764, 142900. https://doi.org/10.1016/j.scitotenv.2020.142900