Process-oriented ecological analysis of a dynamic riparian ecosystem: the lower river Allier (France)

Une analyse écologique orientée vers des processus d'un système riverain dynamique : la rivière Allier aval (France)

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RÉSUMÉ

Les écosystèmes riverains sont des écosystèmes dynamiques soumis aux processus hydrogéomorphologiques avec une forte hétérogénéité géomorphologique, sédimentologique et hydrologique et de nombreux services écosystémiques rendus à la société. Ils font partie des écosystèmes les plus riches en termes de diversité des espèces. Dans le contexte européen, la rivière Allier aval est une des dernières rivières avec des sections à forte mobilité latérale. L'analyse historique a démontré cette forte mobilité latérale des chenaux durant le siècle dernier. Des processus spatio-temporels d'une section de rivière très mobile ont été étudiés à travers l'analyse de la mosaïque des types de végétation, les phases de succession, ainsi que les paramètres physiques des habitats. Comprendre le fonctionnement et l'évolution des écosystèmes riverains dans des systèmes naturels ou proches de l'état naturel est essentiel pour la restauration des cours d'eau très dégradés, afin de permettre la mise en place de stratégies de réhabilitations durables qui considèrent les besoins de la société et les processus naturels.

ABSTRACT

Riparian ecosystems are highly dynamic ecosystems subjected to hydrogeomorphological processes. Their geomorphological, sedimentological and hydrological heterogeneity makes them one of the richest ecosystems in terms of species diversity. In addition, riparian zones also provide numerous ecosystem functions and services to society. In the European context, the lower river Allier (France) is one of the last remaining rivers with laterally dynamic sections. Its historical evaluation has shown repeated river bed displacements during the last century. Spatio-temporal processes on a highly mobile river section of the lower river Allier have been studied analysing the mosaic of vegetation types and successional phases as well as physical habitat parameters. Understanding riparian ecosystem functioning and evolution in natural or nearly natural systems is essential for river restoration practices in highly degraded rivers. This understanding may lead to the establishment of better sustainable river rehabilitation targets that consider societal needs and natural processes.

KEYWORDS

Floodplain vegetation, river Allier, spatio-temporal processes, vegetation succession

1 INTRODUCTION

Floodplains are complex and highly dynamic ecosystems that endure multiple anthropogenic impacts, such as damming, channelization, groundwater pumping and intense land use. These hydrological and morphological alterations in turn lead to a simplification of habitats. Riparian ecosystems are intimately tied to physical, chemical, and biological processes varying in both space and time. Important physical processes are linked to hydro-geomorphological disturbances caused by floods. Riparian vegetation is adapted to frequent disturbances and extreme habitat conditions. In natural floodplains, it is possible to identify a shifting habitat mosaic dynamism that fosters a high biodiversity (Tockner *et al.*, 2010) as a result of the interaction of sediment erosion and deposition, exchanges between groundwater and surface water and plant succession.

As most European rivers are channelized and/or regulated and nearly all floodplains have been degraded, it is essential for river restoration practices to analyse both spatial distribution of vegetation types and processes and temporal aspects in as possible near to natural systems.

The present study focuses on a free-flowing and highly dynamic meandering river section of the river Allier (France). The aim of this study was to design and apply a methodology that integrates a field spatial analysis and a temporal evolution desk study of the interaction of hydromorphological processes and vegetation successional evolution within the floodplain.

A main contribution is expected in terms of helping understanding complex interactions that are now lost in highly degraded rivers. This may lead to establish sustainable river rehabilitation targets that better balance societal needs and natural processes (Corenblit *et al.*, 2013).

2 METHODOLOGY

The river Allier rises at 1485 m a.s.l. in Lozère, southeast France in the Massif Central, and flows 425 km in a south-north direction until joining the Loire River at the Bec d'Allier (67 m a.s.l.). Average annual rainfall is 779 mm, with maximum rainfall typically occurring from May to September (source: Meteo France, station de Vichy). The study site is located in the lower course of the Allier River, 8 km south the village of Moulins. The site length is 3.5 km and the average altitude is 210 m a.s.l. It is a mobile meandering river section without major flow regulations. The reach has a permanent flow and is characterized by a pluvial discharge regime, with a mean annual discharge of 118 m^3s^{-1} (Châtel-de-Neuvre). The 50-year-flood is 1600 m^3s^{-1} (source: Banque Hydro). The study area encompasses the near-natural vegetation of the floodplain without considering non-natural vegetation types, such as agricultural areas and infrastructures. The site was used for intensive grazing in former times and declared as nature reserve in 1994 (*Réserve naturelle du Val d'Allier*).

Based on aerial photographs from 2013 (source: Centre Régional Auvergnat de l'Information Géographique) the vegetation was mapped area-wide in the field (1:2000) in terms of ecological functional types, organized into succession series (aggradation, sedimentation and siltation), which in turn are composed by 18 different vegetation types and by primary and secondary successional phases of initial, pioneer, herb, shrub, early successional woodland, established forest and mature phase. In addition, for each patch mapped, the age of the individuals of black poplar (*Populus nigra L.*) and white willow (*Salix alba L.*), the percentage of selected neophytes, the total vegetation cover and vegetation cover of tree, shrub, herb and moss layer were determined.

Additionally, physical parameters were evaluated within each patch, including soil characteristics such as the cover percentage of every substrate type (according to its grain size), soil moisture, dimension of the humus and litter layer; and hydromorphologic characteristics, such as geomorphologic disturbance (five classes from very high to very low/no impact), flood inundation (five classes from very high to very low/no impact), groundwater table depth and average elevation to mean flow. Complementary, grazing intensity was assessed as a surrogate for land use intensity.

The historical evaluation of landscape mosaics is based on Geerling *et al.* (2006) and unpublished data. Existing ecotope maps were used for the years 1954, 1960, 1967, 1978, 1983, 1985, 2000, 2005, 2014.

3 RESULTS AND DISCUSSION

The river Allier is characterized by a constantly displacement of its bed and evolution of riverine wetlands. It has large open gravel areas and pioneer patches and near to natural riverine forests. For example, in the one kilometer meander length of the river section 500 m to 1200 m SE of *Les Guenaudins*, the main channel oscillates and its bed has changed laterally on average 20 m per year between 1954 and 1967. Between 1967 and 1978 it broke through longitudinally about on average 100 m per year before returning to the former bed in 2000. In 1976 there were two big flood events with more than 1000 m^3s^{-1} discharge, and in 1977 one with a discharge of 800 m^3s^{-1}. Between 2008 and 2011 there was another breakthrough. The new side channel widened until 2014. The repetition of the former displacement series is to be expected, and the same processes will recur now. When the main channel displaces, many side channels and riverine wetland zones remain despite the gravelly ground due to the high ground water table.

The study site is characterized by an immense bed load, and a huge bank zone that is formed mainly by aggradation and erosion. These morphodynamic processes can lead to the completely disruption of forest patches. The river Allier deposits high gravel bars nearby the bank zone. These areas are, especially in summer, extremely dry. For that reason, pioneer patches remain open for long periods and are populated by a primary succession of *Sedum spp.* and dry grassland species, such as *Corynephorus canescens*. *Populus nigra* is one of the few tree species which is able to establish here by suckers; and grassland changes to open poplar woodland after 10 to 20 years. Preliminary results show that *P. nigra*, which recruits at these aggregated higher gravel bars, seems to be mostly clonal. In most cases the trees are polycorm, the stocks are relatively open for some decades and are characterized by different age groups. Sites with deeper topsoils are often dominated by dense *P. nigra* forests. Most populations of *P. nigra* are relatively young (15-30 years). There are only sporadic older poplar forests; the oldest stands are not much older than 45 to 50 years. These locations are periodically flooded and connected to the groundwater. The occurrence of extensive poplar forest with mostly monocorm individuals of the same age class suggests that these cohorts are mostly based on sexual reproduction by seedlings. Their location and spatial extent vary greatly according to interannual oscillation of climate and the hydrological regime. The understanding of the ratio between vegetative and sexual reproduction of *P.* nigra is complicated within the active tract of the study reach of the river Allier.

Recruitment of *Salix alba* takes place on islands and sand bars at the river, adjacent to backwaters and water bodies in the riparian zone (plesiopotamon/paleopotamon). In the study area, white willow forests are often found in silted former side channels; they are flooded over long periods, rich in nutrients and characterized by wet soil conditions.

Only small patches of hardwood forest still exist in the study area. We observed that more elevated patches of potential hardwood forest were logged and used for grazing. In those areas where the pasture land has been abandoned, a secondary succession has been initiated, which usually proceeds within a few decades. On former meadows now *Crataegus monogyna, C. laevigata* shrubs are situated where succession leads towards hardwood forest. English oaks (*Quercus robur*) are frequently present within *Crataegus spp.* shrubs. Secondary succession proceeds differently from primary succession. Recently, large parts of the floodplain were influenced by grazing; now fewer areas are affected by still partially intensive grazing. At present, the floodplain is subject to browsing by deer and wild boar.

LIST OF REFERENCES

Corenblit, D., Fort, M., Arnaud-Fasetta, G., Melun, G., Douseau, J. Uemura, Y., Steiger, J. (2013). Toward a functional compromise between society and Mediterranean fluvial hydrosystems in France? In: Europaean Continental Hydrosystems under Changing Water Policy, Arnaud-Fassetta, G., Masson, E., Reynard, E. (Ed.), Pfeil, München, 27-36.

Geerling, G.W., Ragas, A.M.J., Leuven, R.S.E.W., van den Berg, J.H., Breedveld, M. (2006). Succession and rejuvenation in floodplains along the river Allier (France). Hydrobiologia, 565, 71-86.

Tockner, K., Pusch, M., Borchardt, D., Lorang, M.S. (2010). Multiple stressors in coupled river-floodplain ecosystem. Freshwater Biology, 55, 135-151.