Multiple stressors and novel ecosystems – riparian forest characteristics and future trends on the Rhône River (France)

Facteurs de stress et nouveaux écosystèmes – caractéristiques actuelles de la ripisylve rhodanienne (France) et projections futures

B. Räpple[1], J.C. Stella[2], H. Piégay[1], C. Gruel[1], E. Franquet[3]

[1] Environnement Ville et Société (EVS), CNRS UMR 5600, ENS de Lyon (France)
[2] State University of New York College of Environmental Science and Forestry, Syracuse, New York (USA)
[3] Aix Marseille Univ., Univ. Avignon, CNRS, IRD, IMBE, Marseille, (France)

RÉSUMÉ

L'influence à long-terme des facteurs de stress agissant sur des fleuves fortement modifiés peut conduire les écosystèmes riverains à évoluer vers de nouveaux états. Sur le Rhône, fleuve chenalisé au cours du 19ème siècle, des ripisylves ont colonisé les champs d'épis établis à l'arrière d'une digue submersible, formant ainsi des casiers de sédimentation (les casiers Girardon). La surface occupée par ces ripisylves a augmenté dans la seconde moitié du 20ème siècle à la suite de la dérivation de l'écoulement dans un canal parallèle au lit naturel permettant une production hydroélectrique et la navigation. Cependant, la structure et la composition actuelle des forêts ressemblent peu à celles des sites de référence, du fait de l'interruption des processus d'érosion latérale. La régénération d'espèces endémiques est rare et la strate basse est dominée par des plantules d'espèces invasives, en particulier *Acer negundo* et *Robinia pseudoacacia*. La structure forestière ne s'organise pas selon une chronoséquence classique. Au contraire, les peuplements les plus vieux, établis sur des surfaces atterries avant la construction des barrages ont des surfaces terrières faibles, comparables aux peuplements installés sur les surfaces atterries après les barrages. En outre la densité arborée y est également plus faible, soulignant une rupture dans la dynamique forestière liée aux ajustements du lit ou à des pressions humaines externes. La richesse spécifique montre pourtant un patron temporel, augmentant de manière constante avec l'âge des surfaces. Dans le cas de la zone riveraine rhodanienne, il s'agit de la combinaison de différents facteurs de stress qui a induit une dérive de l'écosystème forestier vers une nouvelle structure et une nouvelle composition.

ABSTRACT

The long-term influence of multiple stressors on large, heavily modified rivers can push riparian ecosystems to novel states. On the Rhône River, which was channelized in the 19th Century, riparian forest stands colonized the formerly active channel within the dike fields, called casiers Girardon. The area of new forest increased after discharge was diverted in the second part of the 20th Century in a series of parallel canals built for hydropower production and navigation. As a result, the current forest structure and composition bear little resemblance to more natural reference areas, as no bank erosion occurs, native tree regeneration is rare, and the understory is dominated by non-native tree seedlings, particularly *Acer negundo* and *Robinia pseudoacacia*. The forest structure does not display the characteristics of a chronosequence from young to old stands. The older, pre-dam forest stands have low basal area, comparable to young, post-dam stands, and comparable tree density, which possibly indicates tree mortality and regeneration in older stages due to channel adjustment, logging or other human intervention in recent decades. Species richness does show a temporal pattern, increasing consistently with stand age. In the case of the Rhône riparian zone, combined stressors interacted strongly to shift the ecosystem to a novel composition and structure.

KEYWORDS

Novel ecosystems, ecogeomorphology, forest dynamics, riparian management, river restoration

1 INTRODUCTION

1.1 Background

Multiple human stressors on rivers can profoundly affect the natural processes and habitat structure of instream and riparian ecosystems. River management influences the distribution and character of riparian forests by changing land use and modifying disturbance regimes and geomorphology (Stella and Bendix, 2018). In this study, we analyzed the cumulative stressors of river channelization and flow regulation on riparian forests along the lower Rhône River in SE France. The Rhône's channel was engineered for navigation prior to 1900, and since then has been dammed and diverted at numerous sites for hydropower and navigation by the Compagnie Nationale du Rhône (CNR). In the context of a large, multi-disciplinary effort to protect, manage and restore the Rhône River corridor for multiple human benefits and natural functions, understanding the response of riparian forests to these historical and current stressors is a critical knowledge gap (Thorel et al., 2017).

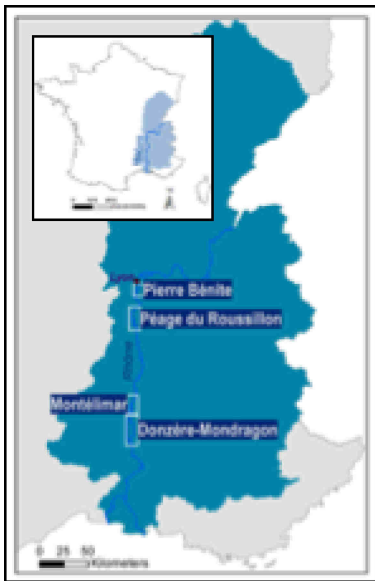

Figure 1. Riparian forest inventory plots were surveyed in four bypassed reaches of the old Rhône River.

1.2 Study objectives

The first objective of the study was to document the current structural characteristics and composition of riparian forest stands that established on dike fields (casiers Girardon) of the old Rhône River, comparing surfaces that were terrestrialized before the CNR dams and those after. Secondly, we investigated the potential drivers of forest composition, structure, and biodiversity, including the influence of abiotic factors such as flood frequency, sediment dynamics, and time since dam construction.

2 METHODS

A total of 82 riparian forest inventory plots were surveyed in four bypassed reaches of the old Rhône River between Lyon and Avignon: Pierre-Bénite, Péage de Roussillon, Montélimar, and Donzère-Mondragon (Figure 1; Table 1). Plot sampling methods were adapted to the French national inventory protocol for riparian areas (Gruel, 2014). Plots were stratified into two management periods, pre-dam (1950's – 1970's) and post-dam (current). Covariates measured for each plot included fine sediment depth, elevation above the active channel, and duration of inundation. Subplots were surveyed for understory species, and coarse woody debris was measured along transects within the plots.

3 RESULTS AND DISCUSSION

3.1 Forest inventory data collection

Floodplain surfaces on the Rhône that terrestrialized in the pre-dam period were 15–130.5 years older than post-dam surfaces, and had deeper deposits of fine sediment and lower duration of inundation at some sites. The understories of the older surfaces had greater development and biomass of understory vegetation and woody shrubs and vines (Figure 2). The woody species richness increased with surface age, and this gradient was consistent across older and younger reference areas that had not been channelized and diverted (Figure 3). Despite the geomorphic and biotic differences between the environments, density and basal area of trees were equivalent between the pre- and post-dam areas (Figure 4). There was very little post-dam recruitment of poplar and willow, which are pioneer species that rely on dynamic geomorphic conditions. In contrast, post-dam floodplains had abundant seedlings of *Acer negundo* (Box elder) and *Robinia pseudoacacia*, which are non-native and invasive in Europe.

Figure 2. Contrasting riparian surfaces between the pre-dam (top) and post-dam (bottom) periods. (Photos by C. Gruel)

Table 1. Minimum forest stand age (years) per reach and management phase, pre-dam versus post-dam. Sites are : Pierre-Bénite (PBN), Péage de Roussillon (PDR), Montélimar (MON) and Donzère-Mondragon (DZM)

Sites	**PBN**		**PDR**		**MON**		**DZM**	
Epoch	pre	post	pre	post	pre	post	pre	post
Mean (years)	66.4	22.3	53.8	22.0	37.9	44.0	62.6	43.2
SD (years)	6.4	10.5	23.3	6.3	23.6	3.2	13.9	10.5

4 CONCLUSIONS

The riparian vegetation composition and structure of the Rhône River dike fields show little evidence of progressive forest succession as is evident on alluvial rivers where natural processes are more intact. The lack of channel dynamism and regulated flow regime likely hasten the transition of forest stands to post-pioneer communities. These novel ecosystems pose challenges for riparian management (Hobbs et al., 2014), and imply that further interventions such as targeted clearing of some riparian areas may be needed to simulate processes of river corridor disturbance and forest regeneration that are no longer viable.

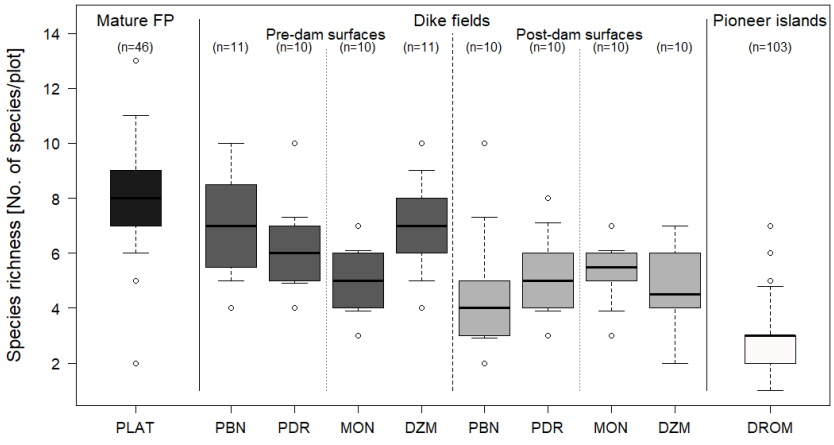

Figure 3. Species richness distributions for riparian landforms of different ages within the bypassed reaches, with older reference sites (left) and younger pioneer sites (right) included for comparison.

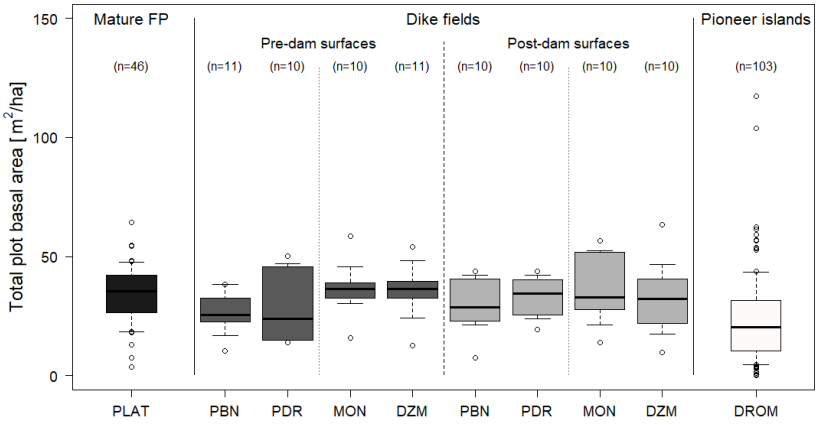

Figure 4. Basal area distributions for riparian landforms of different ages within the bypassed reaches, with older reference sites (left) and younger pioneer sites (right) included for comparison.

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