Restoration Of Alienated Floodplain Channels: Effects On Interstitial Assemblages

Pierre Marmonier[1], Cécile Claret[2] & Marie-José Dole-Olivier[2]

SUMMARY: Changes in composition, structure, and diversity of interstitial assemblages were studied in an alienated channel (the Rossillon backwater) before and after restoration. Regulation of the Rhône River caused most of the floodplain backwater to progressively dry because of fine sediment deposition and a fall in groundwater level. Restoration works entailed dredging fine sediment deposits to promote surface-groundwater exchanges to reverse terrestrialization processes. Interstitial fauna was sampled using the Bou-Rouch method in three stations at two depths (-50 and -100 cm deep), and three seasons (April, July, and November) in 1987 and 1995. Before restoration, the interstitial habitats of Rossillon backwater harboured only a limited invertebrate fauna, low in diversity and abundance. After restoration, assemblages changed markedly in the upstream part of the channel. The dredging of fine sediments increased exchanges between groundwater and surface water, enhancing the abundance and taxonomic richness of interstitial assemblages. Invertebrates feeding on vegetation became dominant. In contrast, in the downstream part of the channel, deposition of fine sediments suspended during restoration works clogged the interstitial zone. There were decreases in total abundance, species richness, and the percentage of herbivores and larger invertebrates. The stygofauna disappeared and densities of meiofauna rose. These results suggest that fine sediment dredging is an efficient method to restore groundwater - surface water exchanges and induce back-succession in floodplain systems. However, future restoration works must employ a different technique (e.g. aspiration) that would reduce production of suspended material and the downstream clogging of sediment interstices.

1. INTRODUCTION

Floodplain wetlands constitute biodiversity hotspots for groundwater fauna, primarily because they represent dynamic contact zones between surface and groundwater systems (Stanford et al., 1996). Increasing human use of floodplains (discharge regulation, embankments, hydro-electric production) substantially modify the environmental conditions for these aquatic organisms (Allan and Flecker, 1993; Dynesius and Nilsson, 1994), because of great changes in fluvial dynamics (Galay, 1983; Bravard *et al.*, 1986a), the natural regime of disturbance (e.g. Ward and Stanford, 1979; Petts, 1984; Dynesius and Nilsson, 1994), and links between surface and groundwater systems (Creuze des Chatelliers and Reygrobellet, 1990). In many European floodplains, restoration works are planned to improve the ecological quality of wetlands associated with large rivers. To reverse terrestrialization processes, dredging of fine organic sediment was carried out, aiming to restore exchanges between surface and groundwater. In this study, we try to evaluate the effectiveness of this dredging for the interstitial assemblages of an alienated channel of the Rhone river (the Rossillon backwater). Changes in composition, structure, and diversity of interstitial faunal were compared before and after restoration work.

2. STUDY SITE

The study site is on the Bregnier-Cordon alluvial plain on the Upper River Rhone (Figure 1). Until the end of the 18th century, this stretch of the Rhone River was characterized by rapid erosion and the development of broad gravel bars and new braided channels (Bravard *et al.*, 1986a, b; Bravard, 1987). The Rossillon backwater is a former braided channel situated on the right bank of the River Rhone. This side arm, closed at its upstream part in 1950, is now connected to a drainage canal at its downstream part (Castella *et al.*, 1984; Figure 1).

Fine sediments were dredged in March 1993 at the upstream part of the backwater, leading to deposition downstream. The upstream alluvial plug has been preserved to prevent permanent surface water inputs from the river (Henry *et al.*, 1995). Three stations were sampled in April, July and November before (1987) and after (1995) the restoration work. RO1 and RO2 were upstream and downstream in the Rossillon backwater. RO3 was located in the downstream drainage canal (which was dug in 1985, two years before the first study and ten years before the second).

[1] Universite de Savoie, GRETI (and ESA-CNRS - 5023), 73376 Le Bourget du Lac, France
[2] Universite Claude-Bernard-Lyon I, Laboratoire d'Hydrobiologie et Ecologie Souterraines, ESA-CNRS - 5023, 69622 Villeurbanne Cedex, France

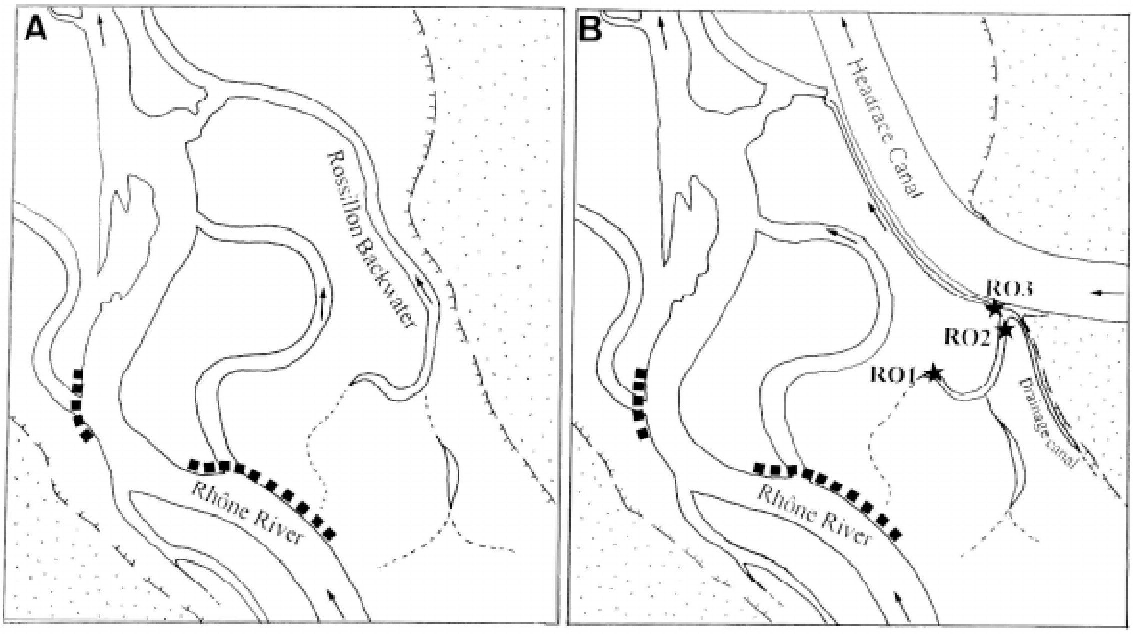

Figure 1 - The Rossillon backwater before (A) and after (B) regulation of the Rhône River. Restoration works took place in 1993 between stations RO1 and RO2 (B). Distance between RO1 and RO2: 600 m. Black squares: loction of the 19th century embankments.

3. MATERIAL AND METHODS

Interstitial invertebrates were collected using the Bou-Rouch sampler (Bou and Rouch, 1967; Bou, 1974) through which 10 l water and sediment were pumped and then filtered through a 300 µm mesh-net. Biodiversity was estimated using five different approaches (Marmonier et al., 1993 Marmonier et al., 1993; Claret et al, submitted): total taxonomic richness, mean taxonomic richness, a diversity index (Shannon & Weaver, 1962), diversity of species traits (trophic status, mode of movement, body size), and diversity of phenological groups (stygoxene, stygophile, and stygobite; Marmonier et al., 1993). Individual abundances, mean taxonomic richness, and mean Shannon-Weaver indices were compared between years (1987 and 1995) using non parametric ANOVA of ranks (Kruskal-Wallis tests).

4. RESULTS AND DISCUSSION

In most cases, abundances did not differ between years (Figure 2). The apparent increase in the upstream station (RO1) between 1987 and 1995 (at both -50 and -100 cm deep in the sediments) is not significant because of high variability of the abundances in 1995. At depth (-100 cm) in the downstream part of the Rossillon backwater, abundances decreased between the two years in RO2 and RO3 ($p<0.05$).

A total of 38 taxa (species, genus, family or class) was identified in the Rossillon backwater. Total taxonomic richness (Table 1) increased in RO1 between 1987 and 1995, from 13 taxa to 24 taxa, minimal changes occurred at RO2 (12 and 13 taxa in 1987 and 1995, respectively) and a decrease was observed in RO3 (from 18 taxa in 1987 to 12 taxa in 1995). The mean taxonomic richness and the mean Shannon-Weaver index varied little over time. There was a slight increase in mean specific richness in RO1, while mean Shannon-Weaver index did not change (Figure 2). In contrast, at RO2, the mean taxonomic richness and mean Shannon-Weaver index decreased between the two periods ($p<0.05$ at -100 cm deep ; Fig. 2). Mean taxonomic richness decreased in RO3 ($p<0.1$), while the mean Shannon-Weaver index did not change (Figure 2).

Biological and ecological characteristics of interstitial organisms changed substantially (Table 1). Before restoration, the upstream part of Rossillon backwater (station RO1) was dominated by taxa associated with stagnant surface water (*Haliplus lineatocollis*, Platycnemididae), rich in organic matter (Oligochaeta), with well developed macrophytes (*Cyclocypris ovum*, *Cypridopsis vidua*). Only two trophic categories were present with equal frequency: detritivores and carnivores. Restoration apparently led to an increase of meiofauna (Cladocera and Ostracoda), insect larvae (Ephemeroptera and Coleoptera), and Mollusca. The Ostracoda present in 1995 (*Candona candida*, *Ilyocypris* sp., and *Pseudocandona albicans*) were frequently found in slowly flowing channels with sandy bottom. Trophic categories diversified: all trophic categories were represented, carnivores significantly decreased, and herbivores became dominant (*Anisus* sp., *Hippeutis complanatus*, *Planorbis* sp., *Haliplus fluviatilis* and *H. lineatocollis*). These observations supported the hypothesis of an increasing renewal of water and the re-establishment of water exchanges between surface and interstitial habitat.

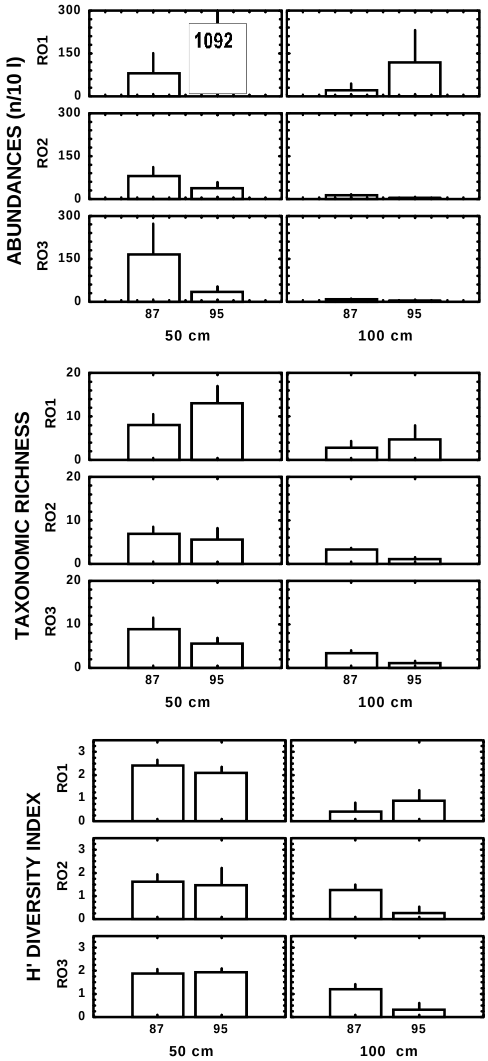

Figure 2: Abundance (number of individuals/ 10 L), taxonomic richness, and Shannon-Weaver diversity indices for the two periods, the two sites, and the two depths (Mean + 1 SE; n = 3; abundance in RO1, in 1995, at 50 cm deep is out of the scale).

In station RO2 before restoration work, fauna was characterized by organisms associated with flowing channels (*Gammarus fossarum*, *Baetis* sp.), rich in organic matter (*Asellus aquaticus*) and vegetation (*Cyclocypris ovum*). After restoration, herbivores and the proportion of large animals decreased, while benthic meiofauna increased (*Alona rectangula, A. quadrangularis, Leydigia quadrangularis*, *Prionocypris zenkeri*).

In station RO3, temporal changes resembled those at station RO2. In 1987, the fauna was characterized by organisms that live in slow flowing environments (e.g. *Gammarus* sp., *Baetis* sp., *Candona candida, Ilyocypris* sp., and *Pseudocandona albicans*) or in standing waters rich in organic matter (*Haliplus lineatocollis*, *Prionocypris zenkeri*). RO3 was the only station where stygobite species (*Niphargus rhenorhodanensis*) was found. This species typifies interstitial habitats of the main channel and of abandoned channels closely related to the main channel (Dole-Olivier et al., 1993). However after restoration, this fauna characteristic of slow flowing habitats had disappeared, together with omnivorous (e.g. *Gammarus* sp.) and most of the herbivorous taxa and the stygobite *Niphargus rhenorhodanensis.* The changes observed in RO2 and RO3 probably reflect decreased water exchanges between surface and interstitial habitats, due to fine sediment deposition.

5. CONCLUSIONS

Restoration caused marked longitudinal changes along the Rossillon backwater. The dredging of fine sediments (Henry *et al.*, 1995) restored water exchanges between surface and interstitial compartments in its upstream part. Biological exchanges were also re-established and led to an increase of total taxonomic richness and the diversity of trophic categories (with dominance of vegetation feeders and stygoxenes in the interstices). However, phreatobites remained absent from this site, probably because of their low rates of recolonization after disturbance.

Table 1: Variation in assemblage composition between 1987 and 1995 in the three studied stations (mean abundances per 10 L calculated for all depths and all dates).

Station RO1	87	95	Station RO2	87	95	Station RO3	87	95
D. gonocephala	0.2		Tardigrada	0.2		*Glossiphonia* sp.	0.2	
V. cristata	0.2		*C. ovum*	1		*C. candida*	0.2	
B. minutissimus	0.2		*A. aquaticus*	0.2		*Ilyocypris* sp.	0.2	
Tardigrada	2.2		*Gammarus* sp.	0.2		*Potamocypris* sp.	0.2	
C. ovum	2.7		*Baetis* sp.	1.8		*P. albicans*	0.2	
Hydra sp.	2.5	1.7	*H. lineatocolis*	0.3		*Gammarus* sp.	0.2	
C. vidua	2.8	0.5	Nematoda	29.2	6.7	*Niphargus rhen.*	2.3	
Harpacticoida	5.2	2.2	Oligochaeta	10.7	7.5	*Baetis* sp.	0.2	
Platycnemis sp.	0.3	0.2	Hydracarina	0.3	0.2	*B. minutissimus*	0.2	
Nematoda	8.2	16.3	Harpacticoida	0.2	0.2	*H. lineatocolis*	0.2	
Oligochaeta	10.5	48.8	Cyclopoida	1.7	1	Nematoda	30.2	8
Cyclopoida	17.0	307	Chironomidae	1.8	2.2	Oligochaeta	19.3	3.3
Chironomidae	0.8	19.7	*Pisidium* sp.		0.5	Hydracaria	1.5	0.8
Pisidium sp.		1.2	*A. rectangula*		0.2	*P. zenkeri*	0.2	0.2
Anisus sp.		0.2	*A. quadrangularis*		0.8	Harpacticoida	0.2	1.7
H. complanatus		0.3	*L. quadrangularis*		0.2	Cyclopoida	21.5	3
Planorbis sp.		6.2	*P. zenkeri*		0.3	*A. aquaticus*	9	0.2
Hydracaria		0.8	*L. striatulus*		0.2	Chironomidae	0.7	0.2
C. sphaericus		1.5	Ceratopogonidae		0.8	*B. affinis*		0.2
S. exospinosus		189				*L. striatulus*		0.2
C. candida		0.7				Ceratopogonidae		0.2
Ilyocypris sp.		0.2				Tipulidae		0.2
P. albicans		3.3						
Gammarus sp.		0.2						
Baetis sp.		0.7						
Caenis sp.		0.5						
H. fluviatilis		1.2						
H. lineatocolis		0.7						
Ceratopogonidae		0.7						
Total taxonomic richness	13	24		12	13		18	12

In the downstream parts of both the Rossillon backwater (station RO2) and the drainage canal (station RO3), restoration work had negative effects, since interstitial assemblages remained low in abundances and diversity in RO2 or decreased further in RO3. Fauna of slow flowing habitats disappeared, omnivorous and herbivorous taxa decreased, and the stygobite amphipod *Niphargus rhenorhodanensis* disappeared. These negative effects were especially apparent at -100 cm deep in the sediments. The deposition of fine suspended sediments due to restoration works enhanced clogging processes. To reduce the production of suspended material and downstream redeposition during dredging of backwaters, fine sediments should be removed by a sediment-sucker (see Henry *et al.*, 1995).

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