REGULATED RIVERS: RESEARCH & MANAGEMENT, VOL. 7, 75–82 (1992)

SPATIAL DISTRIBUTION OF INTERSTITIAL ASSEMBLAGES IN THE FLOODPLAIN OF THE RHÔNE RIVER

P. MARMONIER*, M. J. DOLE-OLIVIER AND M. CREUZÉ DES CHÂTELLIERS
Hydrobiologie et Ecologie Souterraines, U.A. CNRS 1451 'Ecologie des Eaux Douces', Université Lyon I, 43 Bd du 11 Novembre 1918, 69622 Villeurbanne, France

ABSTRACT

Interstitial invertebrate assemblages of the Rhône River were studied at the scale of the entire alluvial plain. Ten stations, located in five former channels, were sampled with a Bou-Rouch pump at 50 and 100 cm depth. The chemical characteristics of the interstitial water allowed the differentiation of stations without hydrological connections with the subterranean habitats, stations fed by surface water coming through the bank sediments and stations fed by true groundwater. The faunal assemblages reflect the difference between connected and isolated stations but did not demonstrate any differences related to the origin of the water. In fact the interstitial assemblages are distributed along a gradient from the margin of the floodplain (stations with a high physical stability associated with the absence of flood periods) to the area close to the main channel regularly influenced by floods. These results demonstrate that both groundwater characteristics and the position of the station in the floodplain influence the spatial distribution of interstitial fauna in the alluvial valley of the Rhône River.

KEY WORDS Floodplain Interstitial assemblages Stygofauna Physical stability Flood

INTRODUCTION

The interstitial fauna of large river floodplains has been studied from a systematic point of view (Hertzog, 1936, 1938), but ecological studies on these habitats have been developed only during the last twenty years (Gibert *et al.*, 1977, 1981; Mestrov and Lattinger-Penko, 1978, 1981; Seyed-Reihani, 1980; Danielopol, 1984, 1989; Dole, 1983a, 1983b, 1984, 1985; Dole and Mathieu, 1984). At the scale of the entire floodplain these ecological studies remain rare (Danielopol, 1976; Dole, 1983a; Dole and Chessel, 1986; Pennak and Ward, 1986; Stanford and Ward, 1988), mainly because the methods for sampling interstitial fauna are difficult to use extensively. This study was our first approach to studying the interstitial fauna of the Rhône River floodplain with an extensive strategy.

The general objective of this work was (1) to know if it was possible to define 'interstitial patches' at the scale of the landscape and (2) to compare the mutual influence of the position of the sampling station and the characteristics of the groundwater on the composition and the structure of interstitial assemblages. The position of the station considered the transversal dimension of the floodplain (from the main channel to the border of the floodplain) and the characteristics of the groundwater consisted of the chemical composition of the water which reflects its origin (surface infiltrated water or real groundwater from the lateral aquifers).

STUDY SITE, MATERIAL AND METHODS

The sampling area, i.e. the Rhône River floodplain in the Jons sector, is located 20 km upstream from Lyon (Figure 1). In this sector the river has abandoned several channels. Some of them are old meanders isolated during the XVII° and the XVIII° centuries and situated on the margins of the floodplain (i.e. the Grand-Gravier, the Chaume and the Plateron dead arms). Others are braided side arms, isolated from the main

*Present address: Département d'Ecologie, Université de Savoie, B.P. 1104, 73011 Chambery, France.

0886-9375/92/010075-08$05.00

Received 20 February 1991
Accepted (revised) 25 September 1991

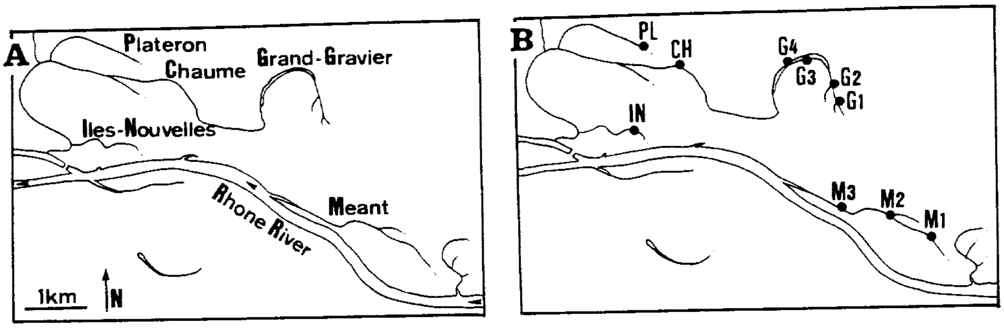

Figure 1. Study area: the floodplain of the Rhône River in the Jons sector. A—location of the five former channels studied. B—location of the ten sampling stations

channel by embankments built during the XIX° century and situated close to the main channel (i.e. the Meant and the Iles-Nouvelles dead arms).

Ten sampling stations were chosen in these dead arms (Figure 1): four in the Grand-Gravier dead arm (G1, G2, G3 and G4), one in the Chaume dead arm (CH), one in the Plateron dead arm (PL), one in the Iles-Nouvelles dead arm (IN) and three in the Meant dead arm (M1, M2 and M3). Six of these stations were located in former meandering channels (G1, G2, G3, G4, CH and PL) and four in former braided channels (IN, M1, M2 and M3). Samples were taken at 50 and 100 cm below the sediment surface (except stations M3 and G1 where samples were impossible at 100 cm depth). Samples were taken in April and July 1987. A supplementary sample has been taken in November for water chemistry only. The flow regime during the sampling period was characterized by an important flood in June 1987 (with a maximum discharge of 2235 $m^3 s^{-1}$), just between the two sampling dates. During this flood, the water of the Rhône River flooded the Meant (+1·5 m), the Iles-Nouvelles (+1·5 m) and the Chaume dead arms (+0·3 m). The water level rose in the Plateron dead arm (+0·2 m); no apparent variation was noticeable in the Grand-Gravier dead arm during this flood.

The fauna was sampled using the Bou-Rouch method (Bou and Rouch, 1967; Bou, 1974). Ten litres of interstitial water were pumped and filtered through a 300 μm meshed net (Marmonier, 1988). Interstitial water for chemical analysis was sampled with a peristaltic pump (WAB type). Four chemical parameters were measured (Dole, 1983a; Marmonier, 1988): temperature and conductivity were measured using a Thermo-conductimeter (WTW), silica by turbidimetry by amino-acid powder and nitrates by the cadmium reduction method. The chemical characteristics used here consist of mean values (based on April, July and November samples) except for temperature.

RESULTS

Chemical characteristics and origin of interstitial water

There were no strong thermal differences between the stations of the studied area. For example, in July 1987 (the summer is the period where thermal differences are the highest between surface and groundwater) interstitial water at most stations was distributed between 11·5 and 12·9°C at 50 cm depth (with an exception: station G2, 14°C; Table I). Very similar results were obtained for the two other periods: between 10·4 and 12·2°C in April, and between 10 and 12·4°C in November.

To differentiate the different types of stations we used the nitrate/silica ratio (Figure 2). Four groups of stations could be distinguished. The first one was characterized by a high amount of silica and a low nitrate content (stations G1 and G2). These two stations are located at the upstream end of the Grand-Gravier dead arm, the chemical characteristics of the water demonstrate a low turn over of interstitial water (high amount of silica) and a lack of hydrological connection with the deep groundwater (low nitrate content). In this area, groundwater generally contains high nitrate levels and low silica concentrations (Reygrobellet and Dole, 1982; Dole, 1983a). The sediments of these stations were clogged or isolated from groundwater.

Table II. Spatial distribution of interstitial fauna in April and July 1987, at 50 and 100 cm depth. Abundance for a ten litres sample. Star: hypogean dwellers

Stations	G3				PL				G4				M2			
Date	Apr		July		Apr		July		Apr		July		Apr		July	
Depth (cm)	50	100	50	100	50	100	50	100	50	100	50	100	50	100	50	100
**P. triquetra*	1	2														
**Niphargus reneil*	1															
**N. casparyi*					2											
**Bathynella sp.*					1			1								
**Crangonyx sp.*									1							
**N. gallicus*									1		1			1		
**Moitessieria lineolata*	50	17	28	14	9	3	5	12			1	3	49	97	6	24
**T. beranecki*	9	2			3											
**Parastenocaris sp.*									1							
**B. diaphanum*	23	17	19	4	19	4	11	37			2	2	6	16	1	
**Hauffenia minuta*	48	10	18	3	9	1	6	4			28	6	110	28	24	4
**N. kochianus*	17	3		6												
**Salentinella sp.*	19	5			30	1	4	3	23		54	37				
**Proasellus sp.*	2			1												
**Microcharon reginae*	203	82	9	21	35	5	3	20	8	2		4	5	74		15
**Niphargus pachypus*			3		7	2	4	4	19	3	36	32	8	14		
Nematoda	58	2			101	129	70	23	45	1	15	2	4	11	1	14
Oligochaeta	15	9	4	4	55	54	57	40	19	4	94	23	14	45	4	17
Bivalvia					1	4	9	3			1	1				
Gastropoda (epigean)						1		1			1	1				
Hydracarina	1				5	1	2	1	2				4	2		1
Cladocera					1				7		19					
Harpacticoida (epigean)	3	2			106	203	928	475	97	1	23	9	4	4		1
Cyclopoida (epigean)	73	58		6	275	52	63	79	13		34	3	30	5	1	3
Ostracoda (epigean)	6	4	1		56	47	11	5	2		9	1	1	1		8
Chironomidae			1						1	1	9	3	41	2	4	1
Diptera (others)					3		3									
Plecoptera		1														
Coleoptera					1								1			
Gammarus sp.							1		5		183	15	5			
Planaria											8		30	2		
Asellidae (epigean)													1			
Ephemeroptera																
**N. rhenorhodanensis*																
**Cryptocandona kieferi*																

All other stations formed a second group and the interstitial fauna (both epigean and hypogean components) were distributed along a gradient. Stations G3, PL and G4 were located at one end of this gradient. These stations were situated far from the main channel and rarely disturbed by the Rhône River floods. The interstitial assemblages at these three stations were characterized by a high diversity of hypogean taxa (Tables II and III), the occurrence of *Pseudocandona triquetra*, *Niphargus renei*, *Bathynella* sp. and *Crangonyx* sp. (rare phreatobites, Ginet, 1982; Dole, 1983a; Marmonier, 1988), and the abundance of *Microcharon reginae* and *Salentinella* sp. (species highly sensitive to natural and anthropogenic disturbance (Marmonier and Dole, 1986; Dole and Coineau, 1987). The stygobite taxa were always more abundant at 50 cm depth (except *Pseudocandona triquetra* in station G3, *Moitessieria lineolata*, *Bythiospeum diaphanum* and *Microcharon reginae* at station PL in July, after water level modification induced by the spring flood). The diversity of epigean organisms was low at these stations. Most of these organisms were microcrustaceans (Harpacticoïdae, Cyclopidae and some Ostracoda, e.g. *Pseudocandona albicans*, *Cypria ophthalmica* and *Cyclocypris ovum*), except at station G4 where *Gammarus* sp. developed an abundant population in summer.

At the other end of this gradient, are stations IN, M1 and M3; stations located close to the main channel and regularly flooded. Their interstitial assemblages were characterized by a high diversity of epigean fauna and a low number of hypogean taxa (Tables II and III). Most of the rare phreatobites disappeared, the very

Table I. Temperature of surface and interstitial waters in July 1987 (in ° C). Sampling was impossible at 100 cm depth in stations M3 and G1

Stations	M1	M2	M3	IN	G1	G2	G3	G4	CH	PL
Surface	14·7	11·1	11·5	11·3	13	13·7	11·6	11·8	16	12·6
50 cm depth	12·6	12·7	13	11·5	12·9	14	12·2	12·5	12	12·9
100 cm depth	12·2	11·7		11·4		13·9	11·8	12·3	11·8	12

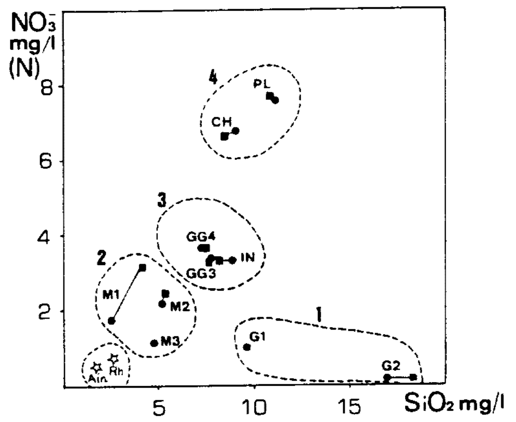

Figure 2. Chemical characteristics of interstitial water: distribution of the sampling stations according to the silica/nitrate ratio. Stars: surface water of the two main rivers (Ain and Rhône Rivers); dots: interstitial waters at 50 cm depth; squares: interstitial waters at 100 cm depth

The three other groups were distributed along an east–west gradient of nitrate enrichment. The second group, i.e. the Meant dead arm stations (M1, M2 and M3), were chemically close to the epigean water of the Rhône and Ain Rivers, characterized by a low nitrate content. These three stations were fed by superficial water infiltrating through sediments without major chemical transformation. The third and fourth groups, i.e. the Grand-Gravier and Iles-Nouvelles stations (G3, G4 and IN), the Plateron and Chaume stations (CH and PL), were characterized by an increase in nitrate content. These stations were fed by deep groundwaters from the Valbonne aquifer, located on the northern side of the valley (Creuzé des Châtelliers, 1991). The increase of nitrate concentrations between the third and fourth groups was linked to agricultural impact on groundwater quality.

Spatial distribution of interstitial fauna

The reorganized data matrix (Table II), the total specific richness and the proportion of hypogean fauna at each station (Table III) allowed us to distinguish two groups of stations. The first group included stations G1 and G2 (located at the upstream end of the Grand-Gravier dead arm). Interstitial assemblages of these two stations were characterized by a weak abundance and a weak species richness, with low diversity of both epigean and hypogean components. Assemblages were dominated by epigean Harpacticoïda (not identified to species level), epigean Ostracoda (*Cypricercus* cf *reticulatus*, *Cypria ophthalmica*, *Cyclocypris ovum*, *Potamocypris* sp. and *Cypridopsis vidua*: ubiquitous species in the Rhône River floodplain), Nematoda and Oligochaeta (not identified). The two hypogean taxa had low abundance. *Niphargus pachypus* (three individuals in station G1) was the most ubiquitous Amphipoda in this sector of the alluvial plain and seemed to prefer the typical clogged habitat, fed by soil water at station G1. *Cryptocandona kieferi* (six individuals), an active Ostracoda (Danielopol, 1984, 1991), colonized the porous superficial sediment at station G2, even if this sediment was not connected to deep groundwater.

Potamocypris sp., *Cypria ophthalmica*, *Prionocypris zenkeri*, *Herpetocypris reptans* and *Cyclocypris ovum*), macrocrustaceans (*Asellus aquaticus*, *Proasellus meridianus* and *Gammarus* sp.) and Insects (Coleoptera, Ephemeroptera and Chironomidae). This epigean fauna was most abundant and most diversified at station M3. At IN, M1 and M3, the interstitial assemblages were similar to those of typical small streams (Bretschko, 1983; Danielopol, 1976; Pennack and Ward, 1986; Voelz and Ward, 1989).

Stations M2 and CH were in an intermediate position on this gradient. The interstitial assemblages of these two stations were characterized by reduced diversity of stygofauna (Tables II and III) and the development of epigean components. The stygofauna was still well developed at station M2 with *Niphargus gallicus*, *Moitessieria lineolata*, *Bythiospeum diaphanum*, *Microcharon reginae* and *Niphargus pachypus*, but these stygobionts were more abundant at 100 cm depth (except for *Hauffenia minuta*). The epigean fauna was not well developed with only some Planaria (*Polycelis* sp.), few Crustaceans (*Gammarus* sp. and some young epigean Asellidae) and Insects (Coleoptera and Chironomidae). At station CH, important seasonal variations could be noticed. The stygofauna was more diversified in April (with the rare phreatobites—*Troglochaetus beranecki*—and sensitive stygobites—*Microcharon reginae*) than after the flood, in July. Conversely, epigean fauna was more diverse in July (with the development of epigean Gastropoda—*Acroloxus* sp.—of *Gammarus* sp., *Caenis* sp. and Planaria—*Polycelis* sp.) than in April.

DISCUSSION AND CONCLUSION

These results demonstrate that both the groundwater characteristics and the position of the station in the floodplain influence the spatial distribution of interstitial fauna in the alluvial plain of the Rhône River. At a first level, the opposition between stations isolated from deep groundwater and stations fed by groundwater (opposition between the upstream end of the Grand-Gravier dead arm and the other stations) is clearly defined by the composition and the structure of interstitial assemblages. The fauna sampled at the stations G1 and G2 has low diversity and is dominated by epigean microcrustaceans which developed in surface water and colonized the subsurface sediments.

At a second level, the origin of groundwater, indicated by its chemical characteristics (i.e. surface water coming from the channel through the sediments or true groundwater from the marginal aquifer), does not appear to influence the interstitial assemblages. The position of stations in the alluvial plain and their relationship with epigean water circulation during floods explains some of the assemblage characteristics. The stations located on the margin of the plain which are rarely flooded (PL, G3 and G4), are characterized by a high diversity of stygofauna, the occurrence of strict phreatobites and species sensitive to disturbance. These stations have a high 'physical stability' (*sensu* Dole and Chessel, 1986) which allows the development of such a fauna in subsurface sediments (only 50 or 100 cm under the surface).

The two stations having an intermediate position on the gradient (CH and M2) were characterized by both an important output of groundwater, which induced high 'physical stability', and the occurrence of floods. The intermediate diversity of their stygofauna reflects the hydrological characteristics of these stations. Station CH, located far from the main channel and rarely flooded, reacted to the spring flood of 1987: one month after this flood one could observe a decrease of stygofauna diversity, an increase in the abundance of epigean fauna (e.g. *Gammarus*, insects larvae...) and the appearance of *Niphargus rhenorhodanensis*, a hypogean Amphipoda generally found in or close to the main channel of the river (Ginet, 1982).

Stations situated close to the Rhône River (IN, M1 and M3) are regularly flooded. This modifies the circulation of interstitial water (input of surface water in the sediments) and induces physical and chemical disturbances in the subsurface sediments. The interstitial assemblages are adapted to this low 'physical stability' and are characterized by a low diversity of stygofauna (with a lack of strict phreatobites and the occurrence of typical species from the main channel), a rich epigean fauna and a low sensitivity to the frequent floods.

Meentemeyer and Box (1987) noted that a landscape may appear to be heterogeneous at one scale but quite homogeneous at another scale. In the Rhône River alluvial plain, when the distribution of interstitial fauna is considered at the scale of the individual dead arms, it appears really patchy. For example, the fauna of the Meant old arm is highly variable from upstream to downstream. This heterogeneity seemed to relate to

Table II. *cont.*

CH				IN				M1				M3		G2				G1	
Apr		July		Apr		July		Apr		July		Apr	July	Apr		July		April	July
50	100	50	100	50	100	50	100	50	100	50	100	50	50	50	100	50	100	50	50
	2																		
	1																		
				3	5	2	7												
		1	1	7	25	10	40												
								3											
1							1		1		4								
								2											
9	6	1			1		3	1			2								
28	3	5	13	2	38		1											3	
6	2	16	9	2	2	13	4	204	6	19	2	125	26	2		1		48	39
24	10	41	12	9	31	23	24	59	3	31	2	68	37	2	5	9	31	6	16
		4		15		26	7	7		13	1								
		58	12	1								2	1					1	8
		3		3				2				5	5					5	2
										4		3	1	14		2	11		
20	10	80	2	1	5	3	6	12	1	3		25	6	3	3	5		30	14
22	1	93	25	8	3	2	3	32	1	68	4	62	136	4	3	22	276	7	12
2		1	1	20	6		2	353	2	103	1	112	13	13	1	31	3	15	10
1		21	1			31	12	14		9	3	67	16	2	1	2	2	1	1
		2	1			2		12		1			1						
												1							
							1	1				5	2						
		694	41	105	5	95	48					185	10						
		50	10	46	7	16	7					19	13						
				1		9	1	9		1		4	45						
		2	1									1	1	3		8			
			1	3	3	3													
																3	3		

sensitive stygobites decreased in abundance (*Salentinella* sp. and *Microcharon reginae*) and the stygofauna was more abundant at one metre depth (for example *Bythiospeum diaphanum*, *Hauffenia minuta* and *Microcharon reginae* in the station IN). An hypogean Amphipoda which is generally sampled in the main channel of the river (*Niphargus rhenorhodanensis*) also occurred in the station IN. The stygofauna disappeared completely at station M3, but this station was only sampled at 50 cm depth and hypogean organisms are generally more abundant at 100 cm depth (Dole, 1983a; Danielopol, 1983). The epigean component was characterized by the development of microcrustaceans (Cyclopoida and Ostracoda, e.g.

Table III. Taxonomic richness and proportion of stygofauna in the interstitial assemblages. The total taxonomic richness includes epigean Ostracoda identified to specific level, Planaria, Plecoptera, and Ephemeroptera identified to genus level

Station	G3	PL	G4	M2	CH	IN	M1	M3	G2	G1
Total specific richness	22	29	27	20	28	25	23	28	13	12
Number of hypogean taxa	11	10	9	6	7	6	4	0	1	1
Hypogean taxa (per cent)	50%	34%	33%	30%	25%	24%	17%	0%	7%	8%

Marmonier, P. and Dole, M. J. 1986. 'Les Amphipodes des sédiments d'un bras court-circuité du Rhône: logique de répartition et réac on aux crues', *Sciences de l'eau*, **5**, 461–486.

Meentemeyer, V. and Box, E. O. 1987. 'Scale effects in landscape studies', in Goigel Turner, M. (Ed.), *Landscape heterogeneity and disturbance*, Ecological studies, 15–34, 239 pp.

Mestrov, M. and Lattinger-Penko, R. 1978. 'Ecological investigations of the influence of a polluted river on surrounding interstitial underground waters', *International Journal of Speleology*, **9**, 331–355.

Mestrov, M. and Lattinger-Penko, R. 1981. 'Investigation of the mutual influence between a polluted river and its hyporheic', *International Journal of Speleology*, **11**, 159–171.

Pennack, R. W. and Ward, J. V. 1986. 'Interstitial faunal communities of the hyporheic and adjacent groundwater biotopes of a Colorado mountain stream', *Archiv für Hydrobiologie, suppl.*, **74**, 356–396.

Reygrobellet, J. L. and Dole, M. J. 1982. 'Structure et fonctionnement des écosystèmes du Haut Rhône français, XVII. Le milieu interstitiel de la "Lône du Grand Gravier"; premiers résultats hydrologiques et faunistiques', *Polskie Archiwum Hydrobiologii*, **29**, 485–500.

Seyed-Reihani, A. 1980. *Etude écologique du milieu interstitiel lié au fleuve Rhône en amont de Lyon*, Thèse de 3ème cycle. Université Claude Bernard, Lyon I, 70 pp.

Stanford, J. A. and Ward, J. V. 1988. 'The hyporheic habitat of river ecosystem', *Nature*, **6185**, 64–66.

Voelz, N. J. and Ward, J. V. 1989. 'Biotic and abiotic gradients in a regulated high elevation rocky Mountain River', *Regulated Rivers: Research and Management*, **3**, 143–152.

the importance of groundwater outflow. In the same way, in the Grand-Gravier former channel, there is a clear distinction between groundwater connected and unconnected areas. But when this spatial distribution is considered at the scale of the entire alluvial plain, the heterogeneity of the fauna appears more gradual than patchy. Natural systems may contain gradients where there are gradual environmental changes, and where patches may or may not have distinct boundaries (Godron and Forman, 1983). The gradient considered in the Rhône River floodplain seems to be a 'physical stability' gradient, linked to the hydrological regime of the river and to the circulation of flood waters. Future studies on other large river floodplains, may identify other factors influencing distributional pattern of interstitial fauna.

ACKNOWLEDGEMENTS

Financial support was provided by CNRS (Program for Interdisciplinary Research on the Environment, U.A. n° 1451); we would like to thank R. Ginet (University of Lyon I) for identification of Niphargides, E. Castella (University of Lyon I) and C. Hakenkamp (University of Maryland) for discussion and criticisms.

REFERENCES

Bou, C. 1974. 'Recherches sur les eaux souterraines. 25. Méthodes de récolte dans les eaux souterraines interstitielles', *Annales de Spéléologie*, **29**, 611-619.

Bou, C. and Rouch, R. 1967. 'Un nouveau champ de recherches sur la faune aquatique souterraine', *Comptes Rendus de l'Académie des Sciences de Paris*, **265**, 369-370.

Bretschko, G. 1983. 'Die Biozönozen der Bettsedimente von Fließgewassern ein Beitrag der Limnologie zur naturnahen Gewässerregulierung'. *Wasserwirtschaft, wasservorsorge, Forschungsarbeiten Bundesministerium für Land und Forestwirtschaft, Wien*, 1-161.

Creuzé des Châtelliers, M. 1991. *Dynamique de répartition des biocénoses interstitielles du Rhône en relation avec des caractéristiques géomorphologiques (secteurs de Brégnier-Cordon, Miribel-Jonage et Donzère-Mondragon)*, Thèse Université Lyon I (France), 1- 160.

Danielopol, D. L. 1976. 'The distribution of the fauna in the interstitial habitats of riverine sediments of the Danube and the Piesting (Austria)', *International Journal of Speleology*, **8**, 23-51.

Danielopol, D. L. 1983. 'Der Einfluss Organischer verschmutzung auf das Grundwasser-ökosystem der Donau im raum Wien und Niederösterreich', *Bundesminist. f. Gesunmdheit u. Umweltschutz*, 1-155.

Danielopol, D. L. 1984. 'Ecological investigations on the alluvial sediments of the Danube in the Vienna area. A phreatobiological project', *Internationale Vereinigung für Theorestitsche und Angewandte Limnologie*, **22**, 1755-1761.

Danielopol, D. L. 1989. 'Groundwater fauna associated with riverine aquifers', *Journal of the North American Benthological Society*, **8**, 18-35.

Danielopol, D. L. 1991. 'Spatial distribution and dispersal of interstitial Crustacea in alluvial sediments of a backwater of the Danube at Vienna'. *Stygologia*, **6**(2) 97-110.

Dole, M. J. 1983a. *Le domaine aquatique souterrain de la plaine alluviale du Rhône à l'Est de Lyon: Ecologie des niveaux supérieurs de la nappe*, Thèse de 3ème cycle, Université Claude Bernard, Lyon I (France), 1-168.

Dole, M. J. 1983b. 'Le domaine aquatique souterrain de la plaine alluviale du Rhône à l'est de Lyon. 1. Diversité hydrologique et biocenotique de trois stations représentatives de la dynamique fluviale', *Vie et Milieu*, **33**, 219-229.

Dole, M. J. 1984. 'Structure biocénotique des niveaux supérieurs de la nappe alluviale à l'est de Lyon', *Mémoires de Biospéologie*, **XI**, 17-26.

Dole, M. J. 1985. 'Le domaine aquatique souterrain de la plaine alluviale de Rhône à l'est de Lyon, 2. Structure verticale des peuplements des niveaux supérieurs de la nappe', *Stygologia*, **1**, 270-291.

Dole, M. J. and Chessel, D. 1986. 'Stabilité physique et biologique des milieux interstitiels. Cas de deux stations du Haut Rhône', *Annales de Limnologie*, **22**, 69-81.

Dole, M. J. and Coineau, N. 1987. 'L'Isopode *Microcharon* (Crustacea Isopoda) abondant dans les eaux interstitielles de l'Est lyonnais. *M. reginae* n.sp., écologie et biogéographie', *Stygologia*, **3**, 200-216.

Dole, M. J. and Mathieu, J. 1984. 'Etude de la "pellicule biologique" dans milieux interstitiels de l'Est lyonnais', *Internationale Vereinigung für Theorestische und Angewandte Limnologie*, **22**, 1745-1750.

Gibert, J., Ginet, R., Mathieu, J., Reygrobellet, J. L., and Seyed-Reihani, A. 1977. 'Structure et fonctionnement des écosystèmes du Haut Rhône français. IV. Le peuplement des eaux phréatiques, premiers résultats', *Annales de limnologie*, **13**, 83-97.

Gibert, J., Ginet, R., Mathieu, J., and Reygrobellet, J. L. 1981. 'Structure et fonctionnement des écosystèmes du Haut Rhône français; IX: analyse des peuplements de deux stations phréatiques alimentant des bras morts', *International Journal of Speleology*, **11**, 141-158.

Ginet, R. 1982. 'Structure et fonctionnement des écosystèmes du Haut Rhône français: XXIV. Les Amphipodes des eaux interstitielles en amont de Lyon', *Polskie Archiwum Hydrobiologii*, **29**, 231-237.

Godron, M. and Forman, R. T. T. 1983. 'Landscape modification and changing ecological characteristics', in *Disturbance and Ecosystems* Mooney, H. A. and Godron, M. (Eds), Springer-Verlag, 12-28.

Hertzog, L. 1936. 'Crustaceen aus unterirdischen Biotopen des Rheintales bei Straßburg. I. Mitteilung', *Zool. Anz.*, **114**, 271-279.

Hertzog, L. 1938. 'Crustaceen aus unterirdischen Biotopen des Rheintales bei Straßburg. III. Mitteilung', *Zool. Anz.*, **123**, 45-56.

Marmonier, P. 1988. *Biocénoses interstitielles et circulation des eaux dans le sous-écoulement d'un chenal aménagé du Haut Rhône français*, Thèse de doctorat, Université Claude Bernard, Lyon I (France).