Link between connectivity and benthic layer functioning: example of the dike fields along the Rhône River

Relation entre connectivité et fonctionnement des sédiments benthiques : exemple des casiers du Rhône

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RÉSUMÉ

La connectivité hydraulique est un facteur clef du fonctionnement des cours d'eau. Elle permet le transfert d'énergie, de nutriments et d'organismes entre le chenal et les diverses annexes fluviales. Cependant, de nombreux cours d'eau ont été endigués affectant la connectivité hydraulique.
Au cours du 19ème siècle, des digues submersibles longitudinales et transversales ont été construites dans le chenal du Rhône moyen et du Bas-Rhône délimitant des casiers plus ou moins ouverts. L'objectif de cette étude est d'explorer le rôle des connexions entre ces annexes fluviales artificielles et le chenal principal en prenant en compte l'activité microbienne et les invertébrés benthiques. Six casiers ont été échantillonnés dans deux secteurs du Bas-Rhône, Péage-de-Roussillon (PDR, secteur régulé) et Arles (ARL, secteur non régulé). La connectivité a été définie par la fréquence de connexion entre les casiers et le chenal principal.
Les activités microbiennes et les invertébrés benthiques ont permis de distinguer les deux secteurs. Le lien entre les fréquences de connexion et les caractéristiques biologiques conduisent à des patrons similaires, en particulier l'individualisation des casiers les moins connectés dans les deux secteurs.

ABSTRACT

Hydrological connectivity is a key driver of river functioning as it allows the transfer of energy, nutrients and organisms between the main channel and the backwaters. However, in many rivers, connectivity was impaired by human built structures like embankments and dike.
During the 19th century, submersible dikes were built in the main channel of the Rhône River delimiting dike fields. This study aims at exploring the role of connection between these artificial backwaters and the main channel considering microbial activities and benthic invertebrates. Six dike fields were sampled in two sectors located on the lower Rhône, Péage-de-Roussillon (PDR, regulated sector) and Arles (ARL, unregulated sector). Connectivity was defined according to the frequency of connection of the dike fields and the main channel.
The differences between the two sectors were evidenced through microbial activities and invertebrate assemblages, but the link between frequency of connectivity and biological features lead to same patterns, especially with an individualization of the less connected dike fields in each sector.

MOTS CLES

Organic matter, C/N, sediment, microbial activities, benthos

1 INTRODUCTION

Hydrological connectivity is a key driver of the transfer of energy, nutrients (organic and mineral) and organisms between the river channel and the floodplain habitats (backwaters s.l.) with major implications for hydrosystem functioning and biodiversity patterns (e.g. Amoros & Roux 1988; Tockner et al., 1999). Natural river-floodplain systems contain a high diversity of water bodies more or less connected with the main channel. However, in many rivers hydrological connectivity was impacted by human activities with consequences on biological compartments and ecological functioning.

During the 19^{th} century, the lower Rhône River was embanked and submersible dikes were built in the main channel. Longitudinal dikes aimed at concentrate the river flow in order to maintain a navigable channel; the transversal dikes were built to decrease the flow velocity and increase sedimentation during floods. These dikes delimit dike fields that can be considered as artificial backwaters with variable connections with main channel likely contributing to maintain the diversity of organism and ecological processes (Nicolas & Pont, 1995).

This study aims at identifying the role of connection of dike fields with the main channel on microbiological and benthic invertebrate diversity.

2 METHODS

Six dike fields were selected in two sectors of the Lower Rhône (Péage-de- Roussillon sector, PDR and Arles sector, ARL) according to the frequency of connection (Fig. 1). In ARL sector, connection frequencies were estimated from previous data (Nicolas & Pont, 1995): R2 and S2 are permanently connected by upstream and downstream pass (R2) and upstream pass (S2). R1, and in a lesser extent F1, are less frequently connected; S3 and S4 which are close to the channel have intermediate frequency of connection. In PDR sector, where discharge is regulated (100 $m^3 s^{-1}$), the dike height was used to estimate the frequency of connection (data provided by B. Räpple): the dike fields 149,126 and 42 are always connected at 100 $m^3 s^{-1}$; the connection of dike fields 10 and 9 is favoured by pass in the dike; the dike field 37 is rarely connected as the dike is 150-cm high.

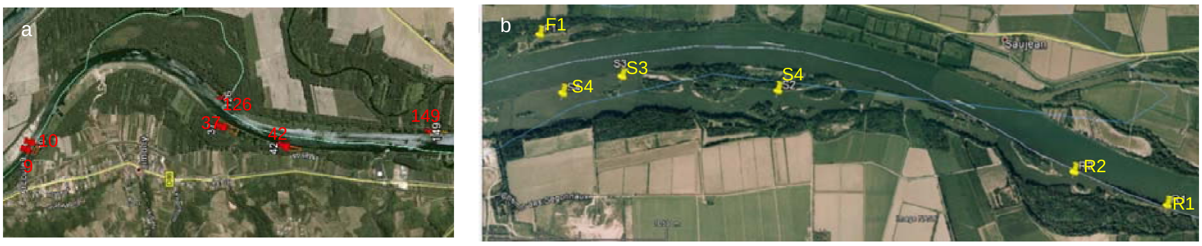


Fig. 1- Localisation of the dike fields in the two studied sectors of the Rhône River, a) Péage de Roussillon; b) Arles (R=Ranchier, S=Saxy, F=Fourques).

Sediments were sampled with an Eckman grab for organic matter content (OM) of sediments, microbial activities (BIOLOG EcoPlates™, 31 carbon substrates) and benthic invertebrates analyses. Organic matter content was measured by loss on ignition (500°C, 4 hours) and C/N ratio with an Elemental Analyzer Flash 1112 Series NC (Thermo Scientific) on the >2 mm sediment fraction.

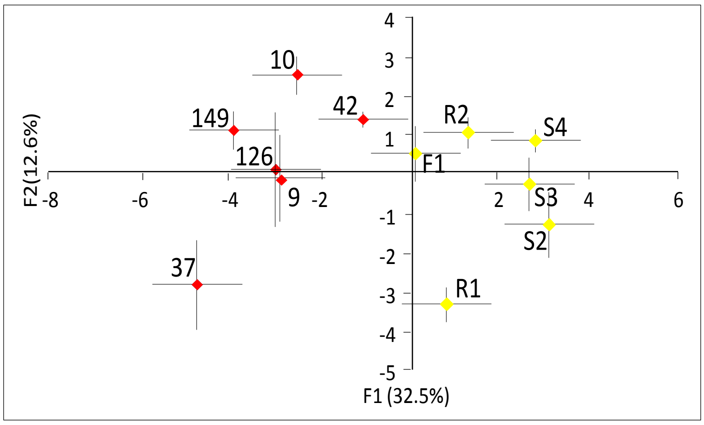
3 RESULTS AND DISCUSSION

3.1 Organic matter content of sediments

Sediments OM content in ARL dike fields ranged from 1.6%(±0.6) in S2 to 3.7%(±0.8) in R1, with a high C/N average value for the sector (average of all dike fields 63.5±5.6). In PDR, OM content in dike fields varied from 3.1% (±1.5) in dike field 10 to 5.7% (±2.5) in dike field 149 with a C/N average for the sector of 33.7± 8.5. The ARL dike fields were less organic than those of PDR likely because of the development of macrophytes and algae in all the PDR dike fields. Even if C/N ratio are lower in PDR than in ARL dike fields, the values remain high characterizing a low OM quality (high C% and low N%) in the two sectors.

3.2 Microbial activities

The oxidation of distinct carbon substrate allowed to characterize the richness of microbial assemblage in dike fields of each sector.



The differences between ARL and PDR sectors are evident on the PCA ordination plot (Fig.2), as microbial assemblages seem to differ in carbon substrate type and number of oxidized substrate. The less frequently connected dike fields (37 and R1 for PDR and ARL, respectively) were clearly individualized likely because microbial assemblages oxidized more slowly and less carbon substrates. This could be explained by less frequent renewal of the sediments that maintain old microbial assemblages less diverse and active.

Fig. 2- Principal Components Analysis of average well colour development (AWCD). Ordination plot of the dike fields on the first two axes of the PCA (average factorial coordinates of sampling points ± SE). Codes refer to dike fields as in Fig. 1.

3.3 Macroinvertebrate assemblages

More than 26000 individuals were collected in total in ARL dike fields, belonging to 22 taxa (order and family), while less than 9000 individuals were collected in PDR sector but richness was higher (36 taxa). In the dike fields of ARL sector the lower richness is observed in the less connected dike field (R1, 5 taxa ± 1), while highest values were observed in dike fields with intermediate connections (S3, S4 and F1; ca. 9 taxa). In PDR sector, the average richness in each dike field better fit with the connection frequency, with only 7±0.6 taxa in the less connected dike field (37) to 20±5.5 taxa in dike field with high connection frequency (149). The lower richness and the absence of clear relationship between connectivity and richness in the ARL dike fields may be explained by the muddy substrate poor in organic matter (do not exceed 4%).

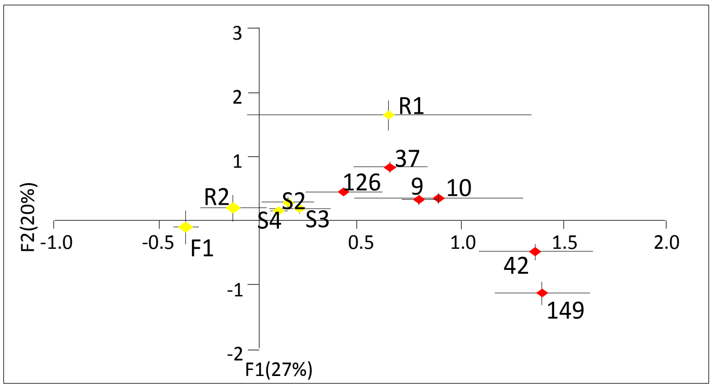


Fig. 3- Factorial Analysis of fauna assemblages. Ordination plot of the dike fields on the first two axes of the CA (average factorial coordinates of sampling points ± SE). Codes refer to dike fields as in Fig. 1.

The PDR and ARL sectors differed in their invertebrate assemblages. The effect of connectivity frequency is less evident than for microbial assemblages, even if the less connected dike field (R1) is clearly separated from other ARL dike field.

4 Conclusion

The ARL and PDR sectors clearly differed in microbial and invertebrate assemblages partly due to their hydrological regime, but show a similar pattern according to the connectivity as weak connected dike field are individualized in each sector. This study highlights convergent structural and functional characteristics. These results support the key role of connectivity to maintain biodiversity of organisms and processes in natural and artificial backwaters.

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