Thermal heterogeneity in subsurface waters across a large braided flood plain

Hétérogénéité thermique des eaux de subsurface d'une plaine alluviale en tresses

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RÉSUMÉ

La température est un facteur clef pour la vie et le métabolisme des cours d'eau. L'hétérogénéité et la variabilité thermiques des eaux de subsurface, en particulier à des profondeurs supérieures à 50 cm ont été peu étudiées par rapports aux eaux de surface. Dans cette étude, nous nous sommes intéressés à l'hétérogénéité et à la variabilité de la température dans des habitats en surface et à 1 mètre de profondeur dans les sédiments dans une plaine alluviale en tresses, durant une période de basses-eaux et une période de hautes-eaux. Cette étude a permis d'illustrer l'hétérogénéité thermique qui existe dans les eaux de surface mais également en profondeur, traduisant une complexité des circulations intra-sédiments et des échanges entre les compartiments de surface et de subsurface, qui contribue à la diversité des conditions environnementales (en particulier, l'existence de 'points frais' dans la plaine alluviale active) et des processus biologiques. Durant les hautes-eaux, cette hétérogénéité se maintient, en particulier par une modification des relations entre les eaux de subsurface et les eaux de surface.

ABSTRACT

Temperature is a key factor for river life and metabolism. The thermal heterogeneity and variability of subsurface water, in particular over 50 cm deep have been poorly studied compared to surface waters. In this study we were interested in the heterogeneity and the variability of temperature in surface habitats and at 1 meter deep within sediments in a braided floodplain, during a low flow period and a high flow period. This study has illustrated the thermal heterogeneity in surface waters, but also within sediments, highlighting the complexity of water flowpath and water exchanges between the floodplain waterbodies and the suburface compartment, that contribute to the diversity of environmental conditions (especially, the presence of 'cold spot') ' and the biological processes. During the higher flow period, this heterogeneity is maintained by changes of relationships between subsurface and surface waters.

MOTS CLES

Heterogeneity, hydrological variability, water-sediment interface.

1 INTRODUCTION

Temperature is a key ecological variable for life and processes in streams and rivers. In particular, it influences composition and distribution of invertebrates in benthic compartment. If heterogeneity of surface temperatures have been well studied (Arscott et al., 2001; Poole & Berman, 2001), less studies have explored thermal heterogeneity and variability in subsurface, especially deep (> 50cm) within sediments and their relationships with surface temperatures.

In this study, we quantify thermal heterogeneity of surface and subsurface waters across a large braided floodplain (Tagliamento, Italy). Specifically, we were interested (1) in illustrating thermal patterns and variability in surface and subsurface habitats during low flow conditions and in (2) determining how temperature patterns respond to a flow pulse.

2 METHODS

The Tagliamento River (north-eastern Italy) is a gravel-bed river considered to be morphologically intact. The presence of islands-braided floodplains is a key feature of this fluvial system.

Water temperature was recorded hourly in 13 waterbodies with data loggers (VEMCO Minilog), in surface and 100 cm deep within the sediment (Fig. 1). A 21-days period in summer was selected, with 10-days stable hydrological conditions (max fragmentation, Period 1) and 11-days characterized by variable water levels and including a flow pulse (water level > 140 cm, Period 2). Hourly recordings of temperature in each habitat and each depth were summarized as daily average, daily minimum and maximum and diel amplitude.

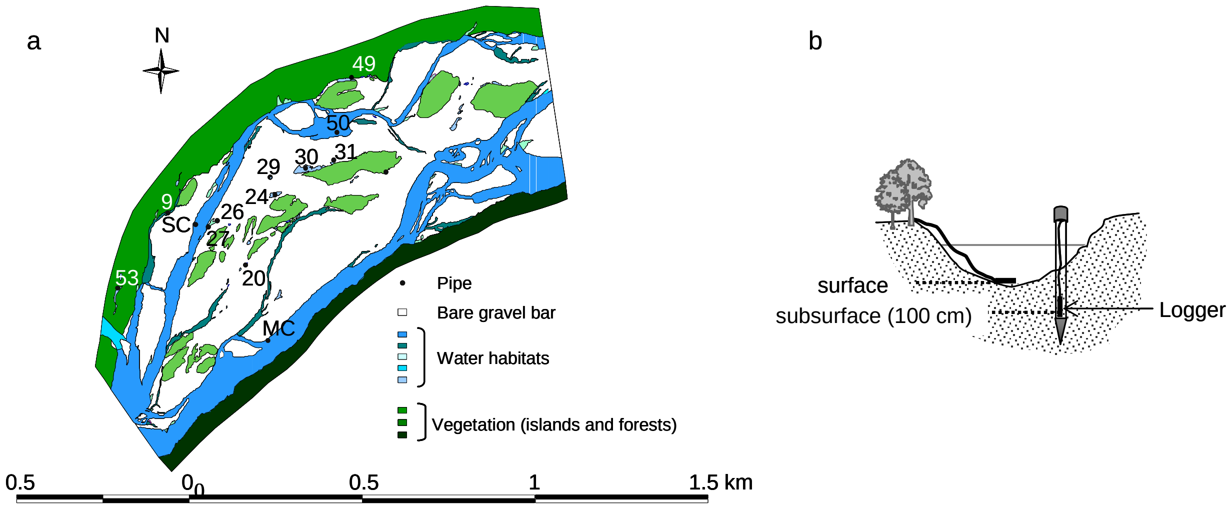

Fig.1 – a) The island-braided reach in May 2000, with the locations of the waterbodies. B) Schematic design for continuous recording of temperature in each waterbody.

3 RESULTS AND DISCUSSION

3.1 Average temperature and diel fluctuations in surface and subsurface waters

During Period 1, a wide range of temperatures (mean daily average) were recorded both in surface (from 23.8 ± 5°C to 10.7 ± 0.2°C), and subsurface (from 18.0 ± 0.1°C to 10.5 ± 0.0°C) compartments. The warmest and the coolest waterbodies in surface were measured in pools with contrasting location across the flood plain (forest and downstream of islands vs. bare gravel bar) and the source water (surface vs. groundwater). The diel amplitude varied from 15°C in an unshaded pool (29) to 0.5°C in a backwater downstream-connected to the main channel (9). This backwater constitutes a 'cold spot' of upwelling water in the floodplain, where some invertebrates can find favourable conditions to survive during summer. In subsurface, thermal differences among waterbodies were lower than in surface, but seems high in pools (ca. 8°C) as well as in the main channel and the connected backwaters (ca. 5°C). The diel amplitudes were lower than in surface (from 2°C in the main channel (MC) to 0°C in water bodies located on the margin of the floodplain (53)). These temperature patterns during low flow periods highlight the complexity of flowpaths within sediments and exchanges between surface and subsurface compartments that contribute to the diversity of environmental conditions and functional processes (like OM decomposition).

3.2 Influence of a water level changes on thermal patterns

During period 2, water level increased up to 140 cm and flooded a large part of the floodplain. Diel average and amplitude of surface temperatures decreased in the warmest pool (20.4 ± 4.4°C), but not in the coldest one where temperature slightly increase (11.2 ± 0.2°C). Similarly, the maximal diel amplitude decrease (13.6°C), while the minimal value slightly increases (0.5°C). These changes in surface waters may highlight an increase of groundwater influence during flood in warmest pools. In subsurface waters, the differences between the warmest and the coldest waterbodies were similar to those observed during low flow conditions (ca. 7°C). Likewise, diel amplitudes do not change markedly (from 1.7°C to 0.0°C). However, in one pool (29) located in a bare gravel bar, diel amplitude at 100 cm deep increased 2 times between the 2 periods. This illustrates that flow pulse do not homogeneize temperature in subsurface, but maintain heterogeneity by increasing upwelling with increasing groundwater level and also downwelling of surface water in pools.

4 CONCLUSIONS

In this island-braided floodplain, subsurface waters are not thermically homogeneous nor stable even deep within sediments. Since braided rivers are dynamic systems largely influenced by natural hydrological events, the modifications of flowpaths along with temperature contribute to diversity of biological assemblages and processes in surface and subsurface compartments. The existence of a thermal mosaic accross floodplain through relationships between surface and subsurface, and especially the presence of 'cold spots', should be considered in stream restoration by promoting the diversity of upwelling and downwelling zones.

LIST OF REFERENCES

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