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Biophysical interactions in fluvial ecosystems: effects of submerged aquatic macrophytes on hydro-morphological processes and ecosystem functioning

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Strong mutual interactions occur at the interface between biota and physical processes in biogeomorphic ecosystems, possibly resulting in self-organized spatial patterns. While these interactions and feedbacks have been increasingly studied in a wide range of landscapes previously, they are still poorly understood in lower energy fluvial systems. Consequently, their impact on the functioning of aquatic ecosystems is largely unknown. In this study we investigate the role of aquatic macrophytes as biological engineers of flow and sediment in lowland streams dominated by water crowfoot (Ranunculus spp.). Using field measurements from two annual growth cycles, we demonstrate that seasonally-changing macrophyte cover maintains relative constant flow rates, both within and between vegetation, despite temporal changes in channel flow discharge. By means of a mathematical model representing the interaction between hydrodynamics and vegetation dynamics, we reveal that scale-dependent feedbacks between plant growth and flow redistribution explain the influence of macrophytes on stabilizing flow rates. Our analysis reveals important implications for ecosystem functions. The creation of fast-flowing channels allows an adequate conveyance of water throughout the annual cycle; yet, patches also have a significant influence on sediment dynamics leading to heterogeneous habitats, thereby facilitating other species. As a last step we investigate the consequences on stream ecosystem functioning, by exploring the relationship between changes in macrophyte cover and the provision of different ecosystem functions (e.g. water conveyance, sediment trapping). Our results highlight that self-organization promotes the combination of multiple ecosystem functions through its effects on hydrological and morphological processes within biogeomorphic ecosystems.