CONTRIBUTIONS FROM RIPARIAN VEGETATION MODELING EXPERIMENTS INTO ECOHYDRAULICS RESEARCH

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A group of researchers from different nationalities and backgrounds have joined to create a working team focused on riparian vegetation modeling, particularly for the assessment of the flow regime change effects on this ecotone. This communication is intended to disclose the most notable outcomes achieved by this work team, and our contribution to ecohydraulics research through the process of better understanding and predicting riparian succession dynamics facing different flow regimes. Several case studies are presented where changes in the riparian habitat lead to modifications on the hydraulic characteristics of river stretches, revealing the importance of riparian vegetation in the study of river ecohydraulics.

1 INTRODUCTION

Ecohydraulics is an emerging sub-discipline of ecohydrology [1] addressing research questions in river science through the study of the interactions between the hydraulic processes of river flow and their influence on aquatic ecology and biology [2]. Since the first appearance of the term ecohydraulics in science journal papers by Jowett & Biggs [3] in 1997 the publication of papers using this term had an exponential increase up to date [4, 5]. However, only a very small percentage of those are related to riparian vegetation, exposing the disregard that is still devoted to riparian vegetation and its influence on river ecohydraulics. As a result, particularly regarding riparian vegetation, the hydrodynamic effects on flow-biota interactions remains much unexplored. Consequently, a group of researchers from different nationalities and backgrounds have joined to create a working team focused on riparian vegetation modeling for the assessment of flow regime change effects on this ecotone and its consequences in various topics of river science. This communication presents a collection of the main results attained by this work team that can contribute to ecohydraulics research.

Research has been performed to increase knowledge concerning large and local scale drivers of riparian vegetation development, riparian vegetation adjustments to river regulation, environmental flow regime requirements for riparian vegetation, and implications of riparian community state for the aquatic biota. In order to do so, different scenarios were considered in globally scattered case studies encompassing flow regimes characterized by different climates and watershed alimentation forms.

2 METHODS

2.1 Riparian vegetation succession drivers

2.1.1 Large scale drivers

Three study sites were selected to encompass Europe's climatic and flow regime variability, and their influences on riparian vegetation succession dynamics. Consequently, the study sites were arranged according to gradients of latitude, altitude, temperature, and watershed alimentation mode (i.e. sources from which watersheds and consequently rivers are fed). In each study site, CASiMiR-vegetation model was used to determine the expected riparian vegetation maps according to the actual and future flow regimes estimated by optimistic and pessimistic climate change scenarios. Expected flow regimes were obtained from previous national assessments. Differences in shear stress and riparian vegetation were assessed by comparison to the natural actual flow regime in each study site. Confidence intervals were built for shear stress sample means and changes in the riparian vegetation succession dynamics were assessed by proportional change in total study site area and within succession phase areas (further information on methodology in [6]).

2.1.2 Small scale drivers

A preliminary study was carried out using one unregulated study site with riparian vegetation in natural conditions. Field survey provided the data for the riparian vegetation map and habitat characterization. The hydraulic characteristics of the study site were estimated using a two-dimensional hydrodynamic model. For the 100-year flooded area data was sampled using a 0.5x0.5m point grid in a geographic information system to extract microhabitat information on groundwater hydrology, morphodynamic disturbance and patch characteristics of succession phases. The influence of such drivers on the patch location and shape of the succession phases was assessed using structural equation modeling techniques [7]. Seen as an extension of the generalized linear models, this modeling method is used to test the validity of theoretical models defining hypothetic causal relationships between variables and to reveal the magnitude of the effects of each variable on the others.

2.2 Riparian vegetation restoration by means of flow regime management

Two study sites were used to assess the influence of managed flow regimes on riparian vegetation. One study site has been regulated for about 40 years and the other one is free flowing. Riparian vegetation was modeled using CASIMIR-vegetation model to determine the expected structural response of riparian vegetation to different managed flow regimes, starting from both regulated and unregulated circumstances. In both case studies, a hydrologic-based method-derived environmental flow regime (hereafter e-flow), including specific guidelines for riparian vegetation requirements in Mediterranean streams, was tested. We compared the results with the natural expected patch mosaic of the study sites. When this e-flow was considered unable to reestablish the natural riparian vegetation, diverse flushing flow regimes were tested to determine the most efficient flushing flow regime in such circumstances. A sediment transport analysis was also performed for the resulting flushing flow regimes in order to determine potential geomorphologic damages due to excessive erosion or sedimentation (further information on methodology in [8]).

2.3 Influence of the riparian habitat on the aquatic habitat

One natural study site was used to model riparian vegetation for 10-year periods according to 3 flow regimes, namely, the natural flow regime, a environmental flow regime regarding only fish requirements (hereafter named fish_eflow) and an environmental flow regime regarding both fish and riparian requirements (hereafter fish&veg_eflow). The resulting riparian patch mosaics were inputted in the hydrodynamic modeling of fish habitat by changing the channel roughness accordingly to the spatial extent of expected riparian succession phases. The hydraulic characteristics of each habitat were assessed and compared along with the resulting Weighted Usable Areas (WUA) of the target fishes (further information on methodology in [9]).

3 RESULTS

3.1 Riparian vegetation succession drivers

3.1.1 Large scale drivers

Results show that riparian vegetation succession is primarily driven by different disturbance processes according to the watershed alimentation form. In every case study, shear stress changes were consistent with the expected climate changed flow regimes and significantly different from the actual flow regime. Morphodynamic disturbance had major importance in driving riparian succession phases, while flooding period and hydric stress have a different significance in the diverse river flow regimes. Furthermore, climate change is expected to affect riparian vegetation in different ways according to the local climate, in which the Mediterranean zones are expected to endure harsh effects. Nonetheless, in every case the younger succession phases will succeed to older and more hydric stress-tolerant without great changes in the overall riparian patch mosaic, but with profound modifications of the specific habitat area of each succession phase.

3.1.2 Small scale drivers assessment

On a mesohabitat scale, the influence of flow regime change can also be expected, influencing both the patch location and the shape of the succession phases. Results from the structural equation modeling revealed that the location of the succession phases appear to be more related to the groundwater hydrology than to the morphodynamic disturbance. The influences upon the shape of the patches seem to be the other way around, although with a much less distinction.

3.2 Riparian vegetation restoration via flow regime management

The pre-defined e-flow regime was able to maintain the riparian patch mosaic near the natural standard in the regulated study case but not in the unregulated case study. In the latter case, the pre-defined e-flow allowed for significant structural change of the riparian patch mosaic, particularly regarding older succession phases. According to the analysis performed in the unregulated study site, the best flushing flow regime consists of 10-year floods interspersed by 3-year floods. Notwithstanding, in both case studies, the sediment transport analysis revealed little topographic variations with a mean topographic change of minus 4mm for the 2-year recurrence interval flood in the regulated study site, and minus 22 and 32 mm respectively for the 3-year and 10-year flood events at the unregulated study site.

3.3 Influence of the riparian habitat on the aquatic habitat

The riparian habitat resulting from the fish_eflow regime permits the encroachment of vegetation into the river channel. In contrast, the riparian habitat resulting from the fish&veg_eflow regime is capable of maintaining a riparian habitat approximate to the natural condition. These circumstances reveal modifications in the hydraulic characteristics of the river stretch (flow velocity and water depth) influenced by the considered riparian habitats. The riparian habitat driven by the fish_eflow regime presents the highest and significantly different channel roughness when compared to the vegetation driven by the fish&veg_eflow, and natural habitats. As a result, changes also occur in flow depth and flow velocity where the fish_eflow riparian habitat creates a circumstance with higher mean depths and lower flow velocities. These are significantly different from the natural and fish&veg_eflow riparian habitats. Fish_eflow WUA differences from the natural availability are greater than the fish&veg_eflow regime which provides a WUA very similar to the natural flow regime.

4 DISCUSSION

The continued effort of this work team has brought several contributions into ecohydraulics research regarding the role of riparian vegetation in influencing the ecohydraulic characteristics of rivers. The riparian vegetation modeling experiments presented revealed diverse ecohydraulic singularities deriving from the adjustment of riparian habitats experiencing flow regime changes along rivers. In future, climate change-induced flow regimes are expected to lead to significant modifications of the natural riparian patch mosaic. These riparian modifications will in turn instill a meaningful variation in flood morphodynamic disturbance by promoting distinct shear stress and sediment transport conditions. Currently, in regulated rivers the ecological degradation of riparian vegetation due to river regulation can be attenuated by means of flow regime management where the best flushing flow regime to achieve this goal should consider floods of both high and low recurrence intervals in order to mimic the natural fluvial disturbance. Those flushing flow regimes are capable of removing accumulated fine sediment, contributing to the channel maintenance and the improvement of physical habitat for aquatic communities; but can do so without expected severe geomorphic impacts or significant water loss from the reservoir's useful capacity. On the contrary, degradation of the riparian habitat will cause adjustments in the hydraulic characteristics of river stretches, changing directly the habitat availability for fish species in the long-term. The definition of the riparian vegetation requirements appear to be crucial in environmental flow requirement assessments, as the maintenance of such communities will preserve aquatic habitat in the long term. This habitat maintenance sustain the habitat premises that underpin the aquatic habitat modeling employed on environmental flow studies. Finally, these outcomes along with the potential of riparian vegetation modeling, have been disclosed over various workshops and courses around the world.

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