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PREFACE

Restoring rivers and floodplains: Hydrology and sediments as drivers of change

Rivers and floodplains have a long history of human perturbation, and they have been significantly impacted by land use intensification and physical degradation. Consequently, on a global scale, these ecosystems rank among those that have seen the greatest loss of biodiversity (Sala et al., 2000; Vörösmarty et al., 2010). Furthermore, it is also recognized worldwide that declines in biodiversity, and the loss of ecosystem services provision, cannot be haltered by protection alone and this have led to a set of international targets including the UN Aichi Biodiversity Target 15 of restoring at least 15% of degraded ecosystems by 2020 (Convention on Biological Diversity, 2010). Rivers are ecosystems with a long tradition for restoration, and in the past more than 3 decades, a substantial number of projects have been undertaken (Feld et al., 2011; Friberg et al., 2016; Ormerod, 2004; Palmer et al., 2005). The outcomes have been mixed in terms of ecosystem improvements (e.g., Kail, Brabec, Poppe, & Januschke, 2015; Palmer, Menninger, & Bernhardt, 2010; Roni, Hanson, & Beechie, 2008), and many projects have not been sufficiently monitored to extract consistent knowledge on geomorphic and biological responses to restoration (Bash & Ryan, 2002; Bernhardt et al., 2005). We therefore must continue improving our understanding of how different types of restoration interventions influence fluvial landscapes and their biodiversity. Process-based restoration focussing on function rather than form is still relatively rare, as is incorporating floodplains into more holistic restoration designs (Friberg et al., 2016). Impairment of natural flow variability (Poff et al., 1997), land use changes (e.g., Pinter, 2005), and various management infrastructure (e.g., Opperman et al., 2009) have physically degraded floodplain habitats and hampered dynamic hydrologic interactions with rivers and groundwater. Flood pulses and their variable characteristics are drivers of developing support a spatially and temporally heterogeneous and dynamic mosaic of habitats in both the river and its floodplain (e.g., Poff, 2002; Tockner, Malard, & Ward, 2000), and restoring riverine ecosystem functions depends on understanding the flows that produce natural floodplain inundation patterns (Benke, 2001). Equally important to understand the flow of water is the issue of sediments. Sediment transport and storage is driven by flow velocities, sediment mobility, and existing instream supplies (Wohl et al., 2015), and this has vital implications for both a dynamic development of geomorphic features and the instream biota (e.g., Friberg et al., 2016; Garcia de Jalon et al., 2017).

The aim of this special issue is to look at the potential of different aspects of flow and sediments in restoring rivers and floodplains and the ecological responses (Figure 1). It consists of seven papers that are derived from a special session on the AGU annual meeting in December 2015 on process-based river restoration and from the EU FP7 project REFORM (REstoring rivers FOR effective catchment Management, http://reformrivers.eu/) that was conducted in the period 2011–2015.

Three papers focus on the effects on changed flow regimes and the possible implications for geomorphological processes and the biota. Whipple, Viers, and Dahlke (2017) used unsupervised k-means clustering analysis to identify ecological meaningful flood regime typologies. They used a 107-year daily flow record from the Cosumnes River of California, USA, for the analysis and included a range of relevant hydrological metrics, such as magnitude, timing, duration, and rate of change of floods, as a basis for the clustering. From a total of 532 individual floods, six flood types were identified that best captured and classified the recorded flood variability, encompassing hydrological features such as high peak flows, seasonal timing of floods, and their duration as well as magnitude. Furthermore, the analysis showed year-to-year differences in flood types depending on primarily climatic conditions with, as an example, the low magnitude and late seasonal flood type primarily occurring in dry years. The study clearly demonstrates the scope of long hydrological time series and how these can be translated into flood typologies that have ecological implications, both in relation to the river channel proper and the floodplain. The knowledge of a natural flood typology is essential to underpin appropriate restoration measures, as it provides an understanding of flows that produce natural inundation patterns. Harrison, Pike, and Boughton (2017) used a large reservoir release to investigate the geomorphic and habitat responses to a flood pulse. They used an innovative combination of field observations, remote sensing, and modelling to assess the effect of the flood and found large-scale geomorphic changes along an 80-km reach, including river channel migration and gravel bar formation. Longitudinal trends gravel transportation and sediment storage reflected channel gradient, but overall the channel was incised and areal extent of pool habitat was doubled. The increased number of pools increased habitat connectivity and was predicted to have a positive effect on anadromous steelhead by a 3-fold increase in juvenile fish habitat. This essentially large-scale experiment shows the potential of using flood pulses to restore form and function in riverine systems that have been deprived of natural hydrological regimes. Kibler and Alipour (2017) evaluate hydrologic alteration in 32 ungauged rivers with diversion hydropower production in Southwestern China. By simulating long-term unregulated discharge records,

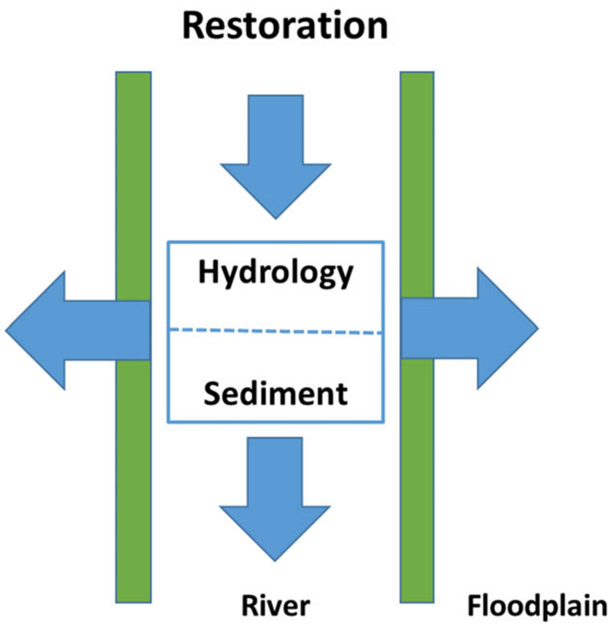

FIGURE 1 Restoring flow and flood pulses are potentially powerful tools in restoring natural sediment dynamics and reinstall connectivity with the floodplain. The arrows indicate longitudinal and lateral movement of water and sediment, with quantities and timing of both being dependent on restoration measures put in place. Depending on degree of degradation, additional measures might be needed such as sediment releases or removal of embankments that otherwise will truncate lateral connectivity of water and sediment between the river and floodplain

they compare changes in flow regime with and without diversion. Statistically significant changes to flow regime metrics were found after hydropower division with decreases in flow magnitude and flow variability, as well as transitions between flows of different magnitudes becoming more abrupt. Direction of observed change was consistent among the rivers, while the intensity of response, and hence level of statistical significance, was variable. The study highlights that hydropower systems without storage reservoirs can profoundly affect river flow regimes and may have the most consistent and severe effect to low-to-moderate flow magnitudes. This will influence river functionality negatively and emphasize that this type of "run-of-river" hydropower needs stringent environmental regulation with mitigation measures put in place to reduce impact on the ecology.

Two papers addressed how in-stream biota responds to hydrological conditions and sediments. Asaeda, Sanjaya, and Kaneko (2017) investigates how mean flow and turbulence influence habitat selection of submerged aquatic plants in rivers. The effects of mean flow and turbulence were tested in a controlled experiment on plants differing in morphology. Plants were exposed to a range of flow intensities and turbulence levels and several morphological and physiological effect parameters were recorded. At high turbulence levels, antioxidant activities and H_2O_2 concentrations were significantly higher in all plants morphologies than at mean flow or in stagnant water, indicating that high turbulence caused physiological stress. Furthermore, structural changes in plant tissue, such as increased accumulation of lignin and cellulose, were observed at high turbulence levels, making the plants more resistant to forces exerted upon them. In contrast to turbulence, changes in mean flow had little influence on plant properties. These findings have implication for understanding habitat selection of submerged macrophytes and the importance of turbulence (and not flow *per se*). This basic ecological understanding can help to predict the submerged macrophyte distribution in altered flow regimes and possible effects of restoration interventions already in the design phase. Jones et al. (2017) explored the link between fine sediments and diatoms in rivers using both a taxonomic and trait approach. Fine sediments are important stressor in agricultural areas due to excess soil erosion and subsequent loss to streams and rivers. The underlying assumption was that the expression of certain species traits, in particular motility, would reflect fine sediment stress to a larger degree than a traditional taxonomic approach. However, they conclude from their study that the response was not sufficiently strong to valid the use of diatoms as indicators of fine sediment stress with the traits tested. Rather, they suggest a novel approach that could be used to better understand the link between fine sediments and diatoms, which could lead to an index. Diatoms are important in the base of the stream food web, and clearly, more work is needed to elucidate how they respond not only fine sediments but also hydromorphological conditions as such.

One paper, Stone, Byrne, and Morrison (2017), used 2-D modelling to predict effects on inundation of restored floodplain connectivity. They found that even small alterations in baseline hydrological conditions in one of their two cases, the Gila River, had clear impacts on floodplain dynamics. The other case, the Rio Grande, the loss of floodplain connectivity resulted in increased incision of the main channel. The results demonstrated the new insights that can be gained with respect to the impacts of hydrologic alterations on floodplain processes. The techniques proposed here can be easily adjusted to accommodate the nuances of other river systems and to address specific processes of concern. This work represents a step forward in attempts to incorporate hydrogeomorphic processes that are important for ecological and riverscape health when addressing the impacts of hydrologic alterations.

In addition to the in-stream biota, the paper by Modrak, Brunzel, and Lorenz (2017) investigated floodplain vegetation at 43 restoration projects, using a paired design that compared restored to non-restored reaches within each project area. They found a significantly higher plant species diversity in restored reaches and that the main drivers of this positive effect were creation of new habitats and improved hydrological connectivity. Analysis of dominant plant traits revealed that the frequency of species preferring regular flooding and with high tolerance to moist conditions increased in floodplains along restored reaches. This study clearly suggests that restoration can increase floodplain vegetation diversity, as well as influencing vegetation patterns, and that increased hydrological connectivity is the key driver in this process. The floodplain vegetation appears to be very responsive with regard to restoration, and also more so than in-stream biota, as long as the relevant abiotic processes are taken into consideration that have the ability to increase habitat heterogeneity in the floodplain.

The seven papers in this issue clearly illustrate the potential for using process-based river restoration but also underpin the need for more ecohydrological studies that links responses of the biota with geomorphic processes at relevant scale. It is evident from several of the studies that rivers and their floodplains need to be restored as one fluvial ecosystem, which is likely to have to large positive consequences for overall biodiversity compared with only restoring river channel form.

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