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Editorial: Challenges and Innovative Solutions in River Sciences

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Editorial on the Research Topic

Challenges and Innovative Solutions in River Sciences

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INTRODUCTION

The Anthropocence describes the time period when humans have become significant modifiers of the Earth's ecosystems (Waters et al., 2016), with dramatic consequences for riverine landscapes. Worldwide, rivers and their associated floodplains have undergone substantial transformations, leading to dramatic reductions of their integrity, natural multi-functionality and the diversity of ecosystem services they provide (Erös and Bányai, 2020). Parallel to this development, the complexity of social, economic, and ecological demands has increased, exercising multiple and often interlinked stressors on river-floodplain systems at different spatial and temporal scales (Birk et al., 2020). River managers have to perceive riverine landscapes as socio-ecological systems, in which human demands, attitudes and perceptions as well as ecological requirements must be collectively considered. This requires new approaches and innovative tools and solutions in river management to harmonize the ecosystem and human needs and to protect riverine landscapes from further degradation, while also considering their critical role for support of aquatic biodiversity (van Rees et al., 2020; Bonar, 2021).

This Research Topic presents selected original research articles from the sixth Biennial Symposium of the International Society for River Science hosted by the Institute of Hydrobiology and Aquatic Ecosystem Management at the University of Natural Resources and Life Sciences, Vienna (BOKU) Austria, from 8–13 September 2019. According to the conference theme "*Riverine landscapes as coupled socio-ecological systems*," the symposium emphasized integrative research on the sustainable use, management, and protection of riverine landscapes and societal implications (Weigelhofer et al., 2021). This special issue focuses on new insights in changes of ecosystem functions and biodiversity and approaches and tools leading to innovative solutions for river management presented at the conference which help to deal with current and future challenges in river research and management.

This special issue covers the following themes:

- Effects of changes to river ecosystems at landscape and global scales
- Innovative solutions to assess these changes
- Long-term strategic and integrative approaches in coupled socio-ecological systems

EFFECTS OF CHANGES TO RIVER ECOSYSTEMS AT LANDSCAPE AND GLOBAL SCALES

Changes of human behavior and interventions at landscape and global scales have multiple consequences for riverine ecosystems, such as altered discharge, temperature and biogeochemical characteristics. Reduced hydrological connectivity of floodplains may impact the phosphorous buffering capacity of floodplain sediments, thus altering the total riverine phosphorous cycle (Preiner et al.). Furthermore, climate change affects aquatic organisms in multiple ways and may intensify prevailing human stressors. Salmonids of alpine rivers showed increased physiological stress and diseases (Borgwardt et al.), while macrophytes responded negatively to simulated climate induced changes of the interplay between flow velocity, DOC and CO_2 (Reitsema et al.).

INNOVATIVE SOLUTIONS TO ASSESS THESE CHANGES

Addressing changes in river systems requires the continuous development of new concepts and tools to tackle specific- and multiple stressors, their altered patterns and effects on ecosystem services in these modified systems more accurately. The morphological structure of riverine landscapes has been largely altered, and human uses have changed them massively at least during the past 150 years, leading to a further change in interactions between humans and river systems (Haidvogl, 2018). Fisheries are a globally important, socially, ecologically and economic relevant ecosystem service. To study and manage social-ecological linkages occurring in salmonid fisheries, the metacoupling framework offers an innovative solution from the United States (Carlson et al.), by assessing and managing socioeconomic and environmental interactions within and between coupled human and natural systems at local, regional, and global scale. Secondary development of decoupled floodplains and conflicting policies present challenges to restoration planning of these systems. By combining single- and multiple-species approaches in an Austrian floodplain, Weigelhofer et al. provides insights into the potential of different restoration measures and trade-offs between different ecological aims. Likewise, a comparison of modeling approaches to estimate nutrient retention in decoupled and reconnected floodplain sections provides evidence of the strengths and weaknesses of the different approaches and the effects of potential restoration measures in Danube floodplains (Natho et al.). Regarding the management of nutrient dynamics, Teubner demonstrated that water transparency thresholds are a useful socio-ecological indicator for macrophyte and algal growth and hence recreational opportunities in an old, urban oxbow lake along the Austrian Danube.

Rivers transport enormous amounts of plastic debris, leading to massive accumulations in the sea (Lechner et al., 2014). This problem calls for new collection methods, as shown for Asian rivers (Owens and Kamil). Future changes in temperature regimes need new equipment to identify cold-water patches as critical refugia for endangered species, as shown by a combination of novel techniques (Cases-Mulet et al.). Invasive plant species are a significant global issue affecting riverine landscapes (Hofstra et al., 2020) and accurate measurements of tissue H_2O_2 concentrations provide a new approach to analyze stress intensity and identify stressors for plant growth as shown for *Egeria densa* in Japanese rivers (Asaeda et al.).

LONG-TERM STRATEGIC- AND INTEGRATIVE APPROACHES IN COUPLED SOCIO-ECOLOGICAL SYSTEMS

The critical situation of stressed and degraded river systems requires not only immediate actions, it also calls for long-term strategic and especially novel integrative approaches to address (river basin) management options at larger scales. Sievert et al. provided such an approach by considering established conservation networks in stream systems in Missouri, which can be an efficient tool to prioritize fish conservation sites throughout river networks. Further, interdisciplinary educational programmes can be a key element to face future challenges while supporting interdisciplinary and management-orientated science at an international scale, as shown for the SMART (Science for MAnagement of Rivers and their Tidal Systems) program (Serlet et al.).

OUTLOOK

These selected examples highlight current progress in freshwater conservation science and river basin management planning and emphasize that more efforts are needed to fully consider riverine landscapes as socio-ecological systems under the view of accelerated changes in the near future. In order to offer holistic solutions for these challenges, a new socio-ecologically driven research agenda is a promising approach. Thus, the following aspects need further attention to support new management schemes in riverine landscapes:

Considering riverine landscapes conceptually as socio-ecological systems would need the incorporation of socio-ecological concepts such as colonization of natural systems (Fischer-Kowalski and Erb, 2016) and social metabolism (Schmid, 2016) to address the coupling between ecological and societal systems. The integration of these concepts would allow to analyze the changing role of rivinere landscapes in the societal metabolism and the elements of the transformation of riverine landscapes.

There is a need to tackle problems and develop indicators more integratively to depict ecological and societal dimensions. New techniques, as for example in optical or acoustic imagery, and interdisciplinary approaches, as well as seeing rivers with their wetlands and surrounding landscape in a holistic way will support this.

The complex setup of stressors acting on our river ecosystems calls for an intensified development of tool-sets, considering future drivers of change and related direct and indirect effects. This will support efforts to tackle conflicting goals of laws and directives and to diagnose more accurately consequences and more tailored management actions at appropriate scales.

More interdisciplinary doctoral programmes need to be developed to address the multi-dimensional nature of these coupled systems and educate a new generation of scientists facilitating the knowledge transfer to application.

Meetings that bring together inter- and transdisciplinary scientists and other actors from across the globe are a critical mechansim to develop strategies for conserving riverine landscapes as coupled socio-ecological systems; participation to jointly define key issues and novel solutions should be encouraged.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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