Innovative approaches in river management and restoration

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Abstract

How research interacts with applications in river management and restoration is a critical question within the Anthropocene era. Improved knowledge regarding the socio-ecological effects of river management and restoration is therefore needed to establish compromises between water uses and riverine ecosystem requirements. This special issue tackles how river management and restoration activities have recently evolved to target cost-efficient and more integrated measures. Some of the contributions showed monitoring feedbacks provide lessons to improve river status and assess success of restoration activities. The range of success indicators considered is continually widening, including more social factors in addition to existing ecological ones. Moreover, win-win and adaptative strategies are also explored to make restoration projects successful and more appreciated by people. Upscaling approaches are also feeding into a growing research field to provide more robust diagnosis for evaluating river status, targeting improvement actions and considering integrative ecological issues in addition to chemical and morphological factors and even fluvial risk assessment.

Text

How research interacts with applications in river management is a critical question within the Anthropocene era, which has been increasingly characterized by rapid global change and a reduction in biodiversity (Perrings et al., 2011; Reid et al., 2019). Throughout the Anthropocene, rivers have been hot spots of research interest, because they support threatened ecosystems that are under high pressure due to anthropogenic demands, e.g., fertile and easily accessible land, water and energy supplies and protection from natural hazards. Furthermore, the increasing development of hydropower (together with other renewable energies) will have important ecological impacts on areas supporting high biodiversity (Zarfl, 2015; Rehbein et al., 2020).

Improved knowledge regarding the socio-ecological effects of river management and restoration is needed to establish compromises between water uses and riverine ecosystem requirements. In particular, we need more feedback from innovative management and restoration experiments, identification of the key ecological processes within river catchments, and improved integration of ecological and socio-economic issues associated with river management (Pahl Wostl et al., 2013; Lamouroux et al., 2015; Angelopoulos et al., 2017).

After initial efforts in the 1960s, focused primarily on water quality issues (Nicolazo, 1994) a wider understanding of the consequences of environmental pollution was developed (Carson, 1962). As a result, many regions and countries, have applied the concept of integrated river basin management, with catchment-scale management plans negotiated among stakeholders and integrated into government / international legislation (Hooper, 2005; Moll,e 2009). For example, the French 1992 Water Law created specific legal and management tools to promote an integrated approach (Piégay et al. 2002) consistent with previous French regulations. A more integrated approach has also promoted by the World Bank and NGOs, such as the WWF in their approaches to the Mekong and other rivers (Goichot, 2004 ; Millington et al., 2006). Central to these approaches in the premise that anthropogenic development must be integrative, sustained, and compatible with conservation of the natural environment. The basin scale has become an appropriate functional scale for the management of rivers, which are seen as a resource, but are also biotopes supporting ecosystems and human society. The integrative approach is considered to be a win-win strategy, allowing stakeholders including decision-makers, land owners, users, and inhabitants to converge on shared solutions. Such approaches must be sustainable and should consider equity, viability and should be tolerable. More importantly, the approach is participative, involving citizens and all water users, and considers riverine environments as a common good to be shared with care (Molle, 2009; Comby et al., 2014).

Since the 1990s, management objectives and policies have focused less on water quality alone, and have increasingly considered biology and hydro-morphology, following the creation of the neologism ‘hydro-morphology’ reflecting the joint consideration of hydrology and geomorphology, a term that is now widespread in the scientific literature (Vaughan and Ormerod, 2010; Rinaldi et al., 2013). With recognition of the substantial alterations made to rivers and the consequences for society of such alterations, efforts to restore rivers have increased. Initially based on a sense of guilt for the damage done to riverine ecosystems, the scientific aims of such actions were ambitious and demanding: return to a structural and functional pre-disturbance state (Cairns, 1991). Over time, the objectives progressively evolved towards improvement of the ecological status and ecosystem services (Dufour and Piégay, 2009). Regulations such as the WFD in Europe in 2000 contributed to this evolution, promoting the improvement of river quality, meaning – according to the WFD– "to reach a good ecological status for rivers and more widely for a set of water bodies (coasts, groundwaters, lakes)". Furthermore, people appreciate nature not only for its utilitarian value, but also for its intrinsic value. Environmental consciousness is progressively growing, and in some cultural contexts rivers now have legal recognition, such as the River Whanganui in New Zealand (Hutchison, 2014) and the Ganga and Yamuna rivers in India (Rosencranz and Kaul, 2017), which are considered 'living entities' or environmental personhoods. These rivers have been granted the same legal rights as a human, resulting in passionate debates within the scientific community and societies worldwide.

For a long time, and even in the present, science has developed independently of day-to-day social expectations. Over a long period of time, river management was based on engineering solutions, and scientists were not involved in these applications. However, since the 1980s this situation changed progressively, with the pace and significance of change varying considerably from one country to another. The present journal, created in 1986, was originally entitled "*Regulated Rivers, Research and Applications*" before becoming "*River Research and Applications*", and its founder, Geoff Petts, was part of this evolution in the use of science to improve practices and river quality, and thereby increasing human well-being (Gurnell et al. 2019). Riverine Studies initially focused on natural sciences have progressively grown to include interdisciplinary groups composed of ecologists, geoscientists, chemists and social scientists, covering different fields and issue associated with riverine systems in their broadest sense. Riverine studies have also become integrative, with the development of integrative sciences research groups focusing on river being formed and growing in different parts of the world, engaging in debates with practitioners, decision-makers, and more widely the general public, sometimes resulting in shared knowledge. The scientific community is not always open to the expectations of society, often because of the stakes related to fundamental scientific research, but also sometimes due to disciplinary corporatism and narrow scientific vision. In a comparable manner, some practitioners may not always be open to incorporating scientists into the debates to develop future water policy, sometimes because of techno-corporatism, but also because of constraints related to resource availability or the commercial interests of the organization. In these instances, citizen stakeholders and associations can then have a significant role in pushing forward integrative science and practice (Matzek et al., 2014 and 2015). While these different constraints slow down collective efforts to solve water resources management problems, they are typically progressively smoothed with practitioners increasingly using science to improve the outcomes of their actions, and the frontier between fundamental and applied research thinning.

The River Rhône catchment in France provides an interesting example of the progressive development of collective and integrative thinking (see Mauz et al., 2012). In the 1980s, with the need to study the ecological impacts of the construction of large dams along the River Rhône and the hydrological disruptions to urban areas, scientific groups emerged that have since generated several generations of transdisciplinary scientists. In the 1990s, interactions between practitioners and scientists increased with the implementation of the 1992 French Water Law, which introduced integrated management and emerging issues regarding river restoration and monitoring. In the 2000s, the interdisciplinary working groups formally joined the international Long Term Ecological Research network (LTER), becoming one of the research teams (ZABR "Zone Atelier du Bassin du Rhône") of the LTER France network. This team has now extended its activities geographically and its relevance to the social sciences, becoming an LTSER site ("S" standing for social; Bretagnolle et al. 2019). Since the beginning of the process, frequent dialogue and exchanges have been maintained to link academic and operational domains, to formulate common questions, and to develop co-constructed research themes. In the 2010s, the group hosted a series of international conferences with a mixed audience (academic and operational), "Novatech" for water quality and "I.S.Rivers" (Integrative Sciences for Rivers, with meetings taking place in 2012, 2015, and 2018, and the next planned for June 2021 (see : http://www.graie.org/ISRivers/a_index.php). Since 2019, a further development has occurred, with the foundation of "EUR H2O'Lyon" (http://www.graie.org/ISRivers/a_index.php), an international graduate school centered on integrated watershed sciences that considers integrative riverine studies from master's to doctorate level, developing strong relationships between practitioners and the international scientific community regarding *riverine studies*.

The research questions developed in the realm of *integrative riverine studies* are numerous. They include conceptual questions and the refinements required to improve current policies. The questions concern the definitions and scope of restoration, resilience, the Anthropocene, ecosystem services, and/or the multifunctionality of rivers. They involve analyses of human behavior, governance, and stakeholder strategies, public controversies, water conflicts, and policies. Increased scientific knowledge regarding the hydrobiological functioning of rivers leads to value being placed on connectivity, bank erosion, and flooding processes, even on in-channel wood. Recognition of these values implies a consideration of other ways of living with rivers, which may be a challenging task. Moving from fighting and exploiting rivers to living with them is both an education and a challenge to citizens. Ongoing research is also developing technical expertise and modelling approaches to assess future changes and evolutionary scenarios. Consideration of climate change and its effects on water discharge and ecosystem responses are also critical. Improving riverine environments means developing innovative solutions to mitigate existing impacts. Examples include the design of environmental flows to mitigate the impacts of dams and river restoration, for which further knowledge is required to improve policies, identify the best solutions, and evaluate successes and failures through monitoring, meta-analysis, and critical appraisal of previous actions. This can help in targeting and refining such policies. Widening of spatial and temporal frameworks is also challenging; it can provide solutions based on a better understanding of the river trajectory and behavior. Most Anthropocene rivers have specific behaviors; we cannot mimic their past functioning, but we can assess and evaluate how they may be improved under present conditions, working with existing processes and implementing process-based solutions based on innovative and interdisciplinary riverine engineering. Improvements in planning, targeting, and the prioritization of actions has also resulted in huge efforts to improve knowledge at the regional, national, continental, and even global scales. Major efforts to provide data and to transform it into knowledge at these varying scales is critical for anticipating and preventing future problems, and for targeting actions to minimize their costs and optimize their effects.

This special issue tackles how river management and restoration activities have recently evolved to target cost-efficient and more integrated management and restoration measures. It illustrates the development of approaches to identify efficient actions addressing societal needs. The special issue also benefits from improved feedback resulting from the increase in long-term surveys following innovative management actions. This special issue comprises contributions presented at the third **I.S.Rivers conference** on “Integrative Science and Sustainable Development of Rivers”, which attracted more than 500 practitioner and scientist participants, in Lyon, France, in June 2018.

In this issue, four articles outline and describe innovative river restoration measures. **Brousse** et al. (2019) focus on sediment replenishment downstream of the Saint-Sauveur dam on a Southern Alpine braided river in France and provide information on its mitigation policy, monitoring, and implementation. Following the removal of a dam on the Sélune River (France), **Ravot** et al. (2019) studied the effects of restoration on riparian communities. Based on colonization indicators, their monitoring indicated that stabilization of reservoir alluvium by vegetation can be a valuable passive restoration strategy. **Arsénio** et al. (2019) also focus on riparian vegetation restoration through the examination of public perception. They analyzed human perceptions of riparian ecosystem changes following passive ecological restoration on two sites in Portugal and France. The results indicate that clear identification of stakeholder groups, effective communication, and public engagement are all required to achieve successful river restoration. **Nakamura** et al. (2019) explore the potential of green infrastructure as an adaptation strategy for climate change, considering flood risk, biodiversity, and social and economic costs. A scenario is evaluated for the Kushiro Wetland, a site of special interest for the conservation of the Red- crowned Crane, a key Japanese flagship species.

Large-scale approaches for assessing and anticipating river management and engineering problems or targeting actions are explored within the subsequent contributions. **Garcia** et al. (2019) used national map resources from four European countries to assess whether it is possible to characterize river corridor evolution over recent decades and over the last two centuries. Opportunities exist to assess such changes in most countries, at the reach and national scales, but widespread application at the continental scale is still limited. Their algorithm (Historical Maps Vectorization Toolbox) was successfully applied across multiple countries. **Massé** et al. (2019) analyzed the concept of 'freedom space' for rivers, which is designed to anticipate flooding and erosion problems. They compared alternative methods for delineating freedom space over several hundred kilometers of rivers in contrasting watersheds in Quebec (Canada). They propose guidelines for an approach that may improve policy based on existing information. **Georges** et al. (2019) investigated the use of available water temperature data from water level monitoring networks over an area of more than 16000 km^2 in southern Belgium. They showed that water level stations represent a promising low-cost network for characterizing the thermal regime of streams. As an example, their approach helped identify areas of thermal risk for brown trout (*Salmo trutta* fario L.). **Nguyen** et al. (2019) established sediment and nutrient budgets at the basin scale over several years to assess the ecological impacts of nutrient outputs from Ho Chi Minh City (Vietnam). Using future scenarios of nutrient inputs (2025–2050), they indicate that estuary eutrophication will escalate without the construction of a large number of wastewater treatment plants.

These different contributions highlight innovative approaches in river management and restoration. Monitoring feedbacks provide lessons to improve river status and assess success of restoration activities. The range of success indicators considered is continually widening, including more social factors in addition to existing ecological ones. Win-win and adaptative strategies are also explored to make restoration projects successful and more appreciated by people. Moreover, upscaling approaches are also feeding into a growing research field to provide more robust diagnosis for evaluating river status, targeting improvement actions and considering integrative ecological issues in addition to chemical and morphological factors and even fluvial risk assessment.

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