Integration of the meta-ecosystem approach into a socio-ecological framework for restoring large rivers

Intégration de l'approche méta-écosystémique dans le cadre socio-écologique pour la restauration des grands cours d'eau

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RÉSUMÉ

Les rivières sont des écosystèmes vitaux qui fournissent une multitude de services écosystémiques essentiels aux sociétés humaines. En outre, les fleuves ont une grande importance stratégique pour les fonctions écologiques et la biodiversité mondiales. Comme de nombreux grands fleuves dans le monde, le Danube est un système socio-écologique très complexe et un haut lieu de la biodiversité et des services écosystémiques, mais il est également affecté par de multiples activités humaines comme la navigation, l'hydroélectricité, le développement urbain ou l'agriculture. La conservation et la restauration des fonctions des écosystèmes et de la fourniture de services est une tâche urgente, mais difficile en raison de la diversité des activités humaines et des objectifs politiques, de la rareté des données par rapport à la complexité des systèmes, de l'hétérogénéité des problèmes environnementaux, des différentes conditions socio-économiques le long des rivières et des héritages des interventions passées, qui nécessitent souvent des mesures de gestion et déterminent les options possibles pour l'avenir. Par conséquent, dans cette présentation, nous explorons le potentiel de l'approche méta-écosystème pour comprendre les interactions dynamiques et les effets des interventions passées afin de projeter le développement futur des réseaux fluviaux connectés et de guider les futures interventions de gestion.

ABSTRACT

Rivers are vital ecosystems providing a multitude of ecosystem services that are essential for human societies. Moreover, rivers have high strategic importance for global ecological functions and biodiversity. Like many large rivers in the world the Danube River is a highly complex socio-ecological system and a hotspot of biodiversity and ecosystem services, but is also affected by multiple human activities like navigation, hydropower, urban development or agriculture. Conservation and restoration of ecosystem functions and service provisioning is an urgent task, but challenging because of the diversity of human activities and policy targets, scarcity of data compared to the complexity of the systems, heterogeneity of environmental problems, different socio-economic conditions along rivers and legacies of past intervention, which often require management measures and determine possible options for the future. Therefore, in this presentation, we explore the potential of the meta-ecosystem approach to understand the dynamic interactions and the effects of past interventions to project the future development of connected river networks and guide future management interventions.

KEYWORDS

River restoration, biodiversity, meta-ecosystem framework, socio-ecology, human pressures

1 BACKGROUND

Human activities profoundly impact large rivers worldwide (Vörösmarty et al. 2013) and change hydrological conditions such as flood patterns. These interferences have brought about new system characteristics in which ecological processes and human activities are closely interwoven. Nowadays, such systems are referred to as social-ecological systems. Although there is a wide appreciation of ecosystem services (ES) provided by riverine landscapes, human interventions caused dramatic losses of riverine habitats, resulting in a functional degradation of fluvial landscapes. Subsequently, this impacted the types and extent of services river landscapes can provide (Hein et al. 2018, MEA 2003).

Overall, it is a societal decision on how far ecosystems – and the corresponding assortment of ES – may be altered. Society as a whole must decide if such changes are acceptable or not. Therefore, decision-making processes are fundamental. To provide a solid basis for such processes, it is, however, necessary to scientifically grasp the processes, dynamics, biodiversity patterns, spatial flows of organisms and resources and related interactions between societies and ecosystems, and to gain a better understanding on how humans fuel ecosystem change – also considering the interaction between ecosystems at larger scales (Gounand et al. 2018b, Renaud et al. 2018). Such research will provide a sound scientific basis to decide upon optimum ecosystem management and restoration strategies (Vermaat et al. 2016).

2 CASE STUDY DANUBE

Compared to the Lower Danube, the Austrian Danube, as part of the Upper Danube, experienced the highest degree of fragmentation and channelization (Tockner et al. 2009). Following the first systematic river regulations of the 19th century, the Austrian Danube was gradually fragmented since the 1950ies by constructing a chain of ten run-of-the-river hydropower plants. In the course of the hydropower plant development also lateral backwater dams were built, which increasingly decoupled the Danube from its floodplain systems. Due to these developments, eleven Danube sections separated by barrages exist, which can be considered detached ecosystems. Overall, these eleven river sections have similar characteristics: they feature a short free-flowing stretch downstream of the dam, which is followed by the head of impoundment that subsequently turns into a long, impounded section. Only two remaining longer free-flowing sections do not conform to this pattern: the Wachau (about 30 km long) and the Danube section east of Vienna (around 50 km long). These are the only river sections of the Austrian Danube with a near-natural flowing character. Within the Wachau, the narrow valley naturally restricts morphological habitat developments, such as the formation of islands, sidearms, and gravel banks. In contrast, the free-flowing section east of Vienna is located in a section where the Danube featured a naturally anabranching morphology (Hohensinner et al. 2013). However, the remaining free-flowing sections are also morphologically altered and exhibit lowered ecological integrity due to diverse river engineering structures, which sharply reduce the lateral connectivity to the floodplain water bodies, and dams upstream, which block bedload transport.

3 APPROACH

To investigate the interplay between aquatic ecology, human interventions, and societal needs along with different spatio-temporal scales – especially in a complex, highly modified system such as the Danube River - different concepts must be integrated, new targeted management approaches formulated, and management measures analysed. In this regard, integrated and improved management frameworks must combine ecologically and societally oriented theories within a resilience perspective (Truchy et al. 2015). Recent results from the AquaCross project (http://aquacross.eu/) showcase how interactions between human activities, pressures and various aquatic ecosystem components (demand side) are affecting aquatic biodiversity and ES provision (supply side) (Lago et al. 2019). Renaud et al. (2018) and Gounand et al. (2018b) addressed the importance of linking societal aspects and meta-ecosystem theory to improve understanding of ecosystem transitions. Further, Gounand et al. (2018a) emphasized the potential of the meta-ecosystem theory to integrate human interventions.

We build on these ideas by combining a meta-ecosystem framework with hydro-morphological components (also including major human interventions) and integrate these with ES as an essential link to human society. The meta-ecosystem framework incorporates metacommunity aspects and food web structures; it describes how spatial flows of energy, materials (abiotic and biotic transport of resources), organisms (dispersal, life-cycle migrations, and movements) and environmental conditions (abiotic environment) between and within different spatial units determine ecosystem functioning, community composition and biodiversity at different spatial scales, also considering the temporal dynamics (Gounand et al. 2018a). Such a riverine meta-ecosystem framework will complement current assessment approaches with a more process-oriented perspective. Studying the role of spatial flows at several scales provides tools to understand the spatial dynamics of regional biodiversity, but also ecosystem functions and services, e.g., via ecological processes (e.g., productivity, recycling) and resource flows (e.g., carbon, water, nitrogen, sediment, organic matter) at various scales.

We approach the Danube as a system, which is subject to spatial and short- and long-term temporal dynamics in both ecological and societal terms. We assume that past interventions into the river have a bearing on present conditions and determine possible options for future river management (Dufour & Piegay 2009). Severe alterations of river morphology and biota have created new types of habitats in the Austrian Danube (Hohensinner et al. 2013) and they have modified biodiversity (Haidvogl et al. 2014), the fluxes of water, sediment or nutrients and ultimately caused reduced or other ecosystem services then a pre-impact state. Further, changing climate has affected species composition and will continue to do so (Pont et al. 2015). It is, thus, required to understand those legacies that affect current river processes and forms and the implications this has for future restoration and management (Wohl 2019). Starting with industrialisation in the 19th century, the societal imprint on the Danube ecosystem intensified in the second half of the 20th century (Vörosmarty et al. 2013). Rationalization, optimization and maximisation of uses became the dominant paradigms of river management (Jakobsson 2002). The needs of shipping and the demand of electricity production called for the systematic channelization of the river and in the end for the disconnection of sidearms, floodplain waters and the floodplains.

Restoration measures and management actions focusing on the local scale might not be sustainable successful, because human alterations occur in multiple ways in the catchment area including land use changes, flow regulation by dams, water diversion and extraction of surface and ground water, and the introduction of invasive species (Cid et al., 2021). Therefore, an approach to combine meta-ecosystem theory with hydro-morphological components (also including major human interventions) and the integration of ecosystem services as a link to human society, is needed for the development of a sustainable river management.

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