Analysing the potential to restore the multi-functionality of floodplain systems by considering ecosystem service quality, quantity and trade-offs

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Abstract
River floodplains are hotspots of productivity and biodiversity and recognized to fulfil vital ecosystem functions and services. Restoration measures of the decoupled Danube floodplains east of Vienna aim to re-establish multi-functionality, that is, ensure navigation, preserve and restore unique fluvial and riparian habitats and re-establish natural processes and service provisioning. Side-channels are proposed for reconnection combined with the removal of embankments and groins. We evaluated how a programme of measures influences the diversity and quantity of specific ecosystem services (ES) and therefore, the overall multi-functionality of the floodplain compared to the current situation. Therefore, regulating ecosystem services (RES), such as nutrient retention and habitat provisioning, were modelled and predicted using multivariate regression models. Also, the potential of cultural ecosystem services (CES) was assessed based on mapping of recreational activities. The impact of proposed measures on ES quantity, that is, quantitative spatial representation, and quality, that is, biodiversity and nature experience, as well as potential synergies and trade-offs were analysed. Our results show clear synergies especially for RES (habitat for the rheotopic community and nutrient retention) and the CES of nature experience. Those services have a weak and local trade-off with the quantitative availability of opportunities for recreation. This pattern could only be detected by considering both, quantitative as well as qualitative aspects of ES. Overall, our results show that the restoration measures have a high potential to increase the multi-functionality of the floodplain system by supporting the provisioning of RES including habitat for endangered species and selected CES.

KEYWORDS
diversity, ecosystem services, nutrient retention, protected species, recreation, river restoration, river-floodplain-system
1 | INTRODUCTION

River floodplains are an integral part of fluvial systems, represent hotspots of productivity and biodiversity (Shiel, Green, & Nielsen, 1998; Tockner & Stanford, 2002) and are recognized as fulfilling vital ecosystem functions and services (Tockner & Stanford, 2002; Tomcscha, Gergel, & Tomlinson, 2017). They are also among the most endangered ecosystems worldwide, especially in Europe where they are threatened by total loss of floodplain and riparian habitats, pollution as well as by the alteration of the hydromorphological conditions (Habersack et al., 2016; Vörösmarty et al., 2010). Therefore, conservation and restoration efforts are gaining importance to maintain and restore ecosystem functions and services (Funk et al., 2019; Schindler et al., 2014, 2016).

In general, ecosystems under more natural conditions show higher multi-functionality related to biodiversity and ecosystem services (ES) (Benayas, Newton, Diaz, & Bullock, 2009; Meli, Benayas, Balvanera, & Ramos, 2014), which can also be assumed for river-floodplain systems with the re-introduction of hydrological dynamics (Funk et al., 2019; Schindler et al., 2014, 2016). However, in complex, partially artificial systems under multiple use, the increase of fluvial dynamics may have different effects on various ES, that is, trade-off and synergies between different sectors can be expected. There is for example a potential trade-off between CES and habitat provisioning (Schindler et al., 2014). A removal of engineering structures may for example decrease recreational opportunities due to the loss of infrastructure to access the area (Vallecillo, La Notte, Zulian, Ferrini, & Maes, 2019), while natural erosion and deposition patterns of a floodplain system are fostered. Specifically for the case study (floodplain national park along the Austrian Danube), the habitat maintenance of the dominant rich stagnotoptic community (community typical of stagnant water bodies) occurring under present conditions may be adversely affected, while the targeted river community and natural processes are fostered by restoration measures (Funk, Gschöpf, Blaschke, Weigelhofer, & Beckendorfer, 2013; Sanon, Hein, Douven, & Winkler, 2012).

The Danube east of Vienna, a historically braided river section, had been constraint by major regulation schemes that started in 1875. Since 1996, the river-floodplain system has the status of a national park and actions and strategic planning to maintain and restore the floodplain ecosystems have been developed. With its position between two capital cities (Vienna and Bratislava) the National park is of exceptional societal importance including its functions for flood protection (Schober, Hauer, & Habersack, 2015), recreation (Sanon et al., 2012), nutrient retention (Tockner, Prenetzdorfer, Reiner, Schiemer, & Ward, 1999) and a high conservation value for a rich stagnotoptic community (Funk et al., 2013).

Since 2003, a large-scale restoration project “The Integrated River Engineering Project” has been in place and is already partially implemented (e.g., Bondar-Kunze et al., 2016). This also needs to consider goals to secure navigation, restoration of the hydrological connectivity of the decoupled Danube floodplains, including side channel reconnection combined with the removal of riverside embankments. It aims to re-establish the ecological functionality of the system that is, preserve and restore unique fluvial and riparian habitats and re-establish natural hydromorphological dynamics (Reckendorfer et al., 2005). Hydrological connectivity, that is, the lateral exchange between river channels and their floodplains, has been identified to be a key variable for biodiversity and the composition of aquatic (e.g., Desjonquères, Rybak, Castella, Llusia, & Sueur, 2018; Leigh & Sheldon, 2009; Paillex, Dolèdec, Castella, Mérigoux, & Aldridge, 2013; Reckendorfer, Baranyi, Funk, & Schiemer, 2006) and terrestrial (e.g., Casco, Neiff, & de Neiff, 2010; Souther, Wallace, Walter, & Watts, 2014) communities. The connectivity patterns are also crucial for ES provisioning including floodwater retention (e.g., Clilverd, Thompson, Heppell, Sayer, & Axmacher, 2016; Schober et al., 2015), nutrient retention (e.g., Natho, Venohr, Henle, & Schulz-Zunker, 2013; Newcomer Johnson, Kaushal, Mayer, Smith, & Sivirichi, 2016) greenhouse gas emission (e.g., Audet, Elsgaard, Larsen, & Hoffmann, 2013; Weltl et al., 2012) and recreation (e.g., Sanon et al., 2012; Woolsey et al., 2007). While there is already direct evidence from literature that the restoration of hydrological connectivity of floodplains has a strong positive effect on the aquatic community in general (e.g., Paillex et al. 2015, Rumm et al., 2018, Straatsma, Bloecker, Lenders, Leuven, & Kleinmans, 2017), the effects of restoration measures on ES provisioning are less often studied in floodplains and wetlands (Meli et al., 2014).

The effect of ecological restoration on the biotic community is often assessed or predicted quantitatively calculating the amount of physical habitat that is available (e.g., weighted usable area approach, Bovee, Lamb, Bartholow, Stalnaker, & Taylor, 1998) or based on biodiversity (e.g., Ferrier, Manion, Elith, & Richardson, 2007; Valerio et al., 2016). Likewise CES have recently been proposed to be divided into two categories (a) quantitative indicators like path length, fishing or bathing areas and other recreational possibilities or (b) indicators for the immaterial quality of the system for nature experience and aesthetic value, for example, species or habitat diversity (Bieling & Plieninger, 2013; Rall, Bieling, Zytynska, & Haase, 2017).

Therefore, the objective of this study was to analyse and predict the impact of the proposed programme of measures on relevant ES for the National Park section along the Austrian Danube comparing to the current situation quantitatively (quantitative spatial availability of ES) and qualitatively (diversity and nature experience). We addressed the following key questions: How will the management measures affect the quantity and quality of the ES and therefore, the multi-functionality of the system? Are there ES trade-offs or synergies and where are they located? Therefore, the analyses of the specific restoration approach may provide a basis for more general strategic restoration planning in regulated large rivers.

2 | METHODS

2.1 | Study system

The Danube River, the second largest river in Europe, is 2,900 km long and drains an area of 817,000 km². At Vienna, the
Danube is a ninth-order river (according to the Strahler system) with a mean annual discharge of about 1950 m³/s and a bankfull discharge of 5,800 m³/s. In 1996, the river–floodplain system east of Vienna was designated as national park (Danube Alluvial National Park, DANP). The size of the national park area is about 93 km² and comprises 65% floodplain forest, 20% total water area and 15% meadows and fields (Reckendorfer et al., 2006). Historically braided, the river–floodplain system has been constrained by the major regulation schemes starting in 1875, and today is threatened by ongoing terrestrialization, loss of floodplain habitat, loss of rheophilic and rheotopic species (species of lotic water bodies) and is dominated by a limnophilic/stagnotopic community (community of stagnant water bodies) (Hein et al., 2016). Therefore, one of the main goals of the national park is the conservation and restoration of this hydrologically dynamic reference state including its high biodiversity and related ES and functions (NPDA, 2019).

### 2.2 Restoration scenario—programme of measures

The proposed restoration measures are described in Reckendorfer et al. (2005), a spatial representation of the relevant measures directly affecting the floodplain area under investigation is presented in Figure 1b. The measures include full reconnection of several side channels and removal of embankments along the main stem of the Danube. Ecological targets are to preserve and restore unique fluvial and riparian habitats and re-establish natural hydromorphological dynamics (Reckendorfer et al., 2005).

### 2.3 Indicators

The selection of ES influenced by floodplain restoration was based on CICES (Haines-Young & Potschin, 2018). In a first step, the list was screened for the relevance of the respective ES in the system (Appendix S1). For RES, two ES “habitat availability for protected species” and “nutrient retention” were chosen, as they were expected to be of high importance and potentially highly influenced by restoration measures. With its status as nature park (IUCN) and Natura 2000 site, the area has a high responsibility for the conservation and restoration of habitats for a wide range of protected species with contrasting habitat requirements (e.g., Funk et al., 2013). Nutrient retention and transformation is a basic ecological function of floodplain systems (Tockner et al., 1999) and (re-)connected floodplains are expected to increase this function significantly in regulated rivers (Hein, Baranyi, Herndl, Wanek, & Schiemer, 2003).

For CES, several recreational services were expected to be especially important as protected areas per se and water in particular is a key element of nature based leisure activities (Ghermandi, 2015; Vallecillo et al., 2019). As the restoration measures were mainly targeting the aquatic and semi-aquatic systems in the area, the focus of the study was on water-based activities, access to aquatic areas and nature experiences related to aquatic and semi-aquatic habitats.

### 2.4 Models and data

RES such as nutrient retention and habitat provisioning were modelled and predicted using multivariate regression models and the potential of CES was assessed based on mapping activities.
2.4.1 | Suitable habitat assessment

Models already used for the evaluation of restoration scenarios in the area of the national park were further developed based on additional available species protected under the EU Habitats directive (92/43/EEC; HB) and Birds directive (2009/147/EC; BD) (water bird and rare fish species) and additional environmental data (distinction between upstream and downstream hydrological connectivity of the side channel systems). For a detailed description of the modelling approach see Funk et al. (2013). Models were classical species distribution models based on a GLM approach, validated using cross-validation and used for prediction. For this study quantitative values were calculated based on the weighted usable area (WUA) approach adapted as weighted usable length (WUL, Torretta, 2014), as areal predictions for water bodies in the restoration scenarios were not exact enough without hydrological modelling. For a list and description of indicators see Appendix S1.

2.4.2 | Nutrient retention

Nitrate-nitrogen (NO3–N) and total phosphorus (TP) mass balances were calculated using nutrient concentration data of past monitoring projects covering the years 1991 to 2017 (e.g., Heller, Hein, Schiemer, & Bornette, 1995; Hein, Baranyi, Reckendorfer, & Schiemer, 2004). Highly significant dependencies on discharge and incoming nutrient concentrations (multivariate adaptive regression splines (Milborrow 2011), single linear regressions) were used to predict nutrient retention in various systems for the status quo and the restoration scenario. Dependend on the degree of connectivity of respective side channel systems, retention rates were modelled based on the available data. For a detailed description of the modelling approach see Natho, Tschikof, and Hein (2020) and Supplementary material S1. For a list and description of indicators see Appendix S1.

2.4.3 | Cultural ES

The quantity of CES was assessed based on mapping potential for activities. GIS layers for all areas where the different activities are permitted (path for walking and biking, area of floodplain water body areas where boating, bathing, angling and ice skating are permitted, respectively) were provided by the National Park authority. Changes in the area’s potential for activities were analysed by mapping direct loss of area due to restoration measures as well as indirect effects due to a loss of accessibility. Quality (diversity of potential for nature experiences) in those zones was analysed by overlaying it with habitat availability. This was addressed as a parameter for the diversity of habitats that can be experienced during a recreational activity (see e.g., Richards, Moggridge, Maltby, & Warren, 2018). Therefore, the GIS layers for the different ES categories were spatially overlaid using ArcGIS 10.3 to determine zones of potential interaction between habitat availability and CES (Figure 1). The interaction zones between RES and CES were used to analyse the change in nature experience due to the restoration measures, that is, habitat predictions were used to describe the change in natural habitat quality that could be experienced during different activities in the national park. For a list and description of indicators see Appendix S1.

2.5 | Quantitative and qualitative evaluation, trade-offs and multi-functionality

For the quantitative evaluation WUL were used as indicators of the habitat provisioning ES, nutrient retention was calculated in kg per side channel for an average hydraulic year and for CES, the total water body length available for each activity was used as a quantitative indicator. A simple additive approach was used for the assessment of the two scenarios where in the first step all indicator values were normalized using vector normalization. In the second step, normalized values were summarized per scenario (following Simple Additive Weighting [SAW] technique). Finally, the restoration scenario was analysed in comparison to the status quo by calculating the loss (sum of deficits compared to the status quo), gain (sum of surplus compared to the status quo), and total balance of both values following Funk et al. (2013).

ES quality was described using habitat diversity, that is, diversity of habitats predicted from species distribution models, and functional diversity, that is, diversity of water bodies ranging from autochthonous to allochthonous controlled systems (Hein et al., 2003). We calculated a dissimilarity index (Bray-Curtis index) used for quantification of beta-diversity (Legendre & De Cáceres, 2013) as well as diversity of ES (Hölting et al., 2019), based on the model outputs for the habitat and retention models, respectively. For the evaluation of the restoration scenario against the status quo, the gain or loss of beta-diversity was calculated for each ES indicator. For simple graphical representation of the change in diversity of habitats and functionality, model outputs from species models (predicted probability of occurrence per species, water body section and scenario) and retention models (predicted nutrient retention values per water body section and scenario) were summarized using a PCA (Principal Component Analysis). The result of the PCA was not used for any further calculation.

The predicted change in the quality and quantity of the ES indicators in the restoration scenario compared to the status quo was interpreted as change in the total multi-functionality of the system.

For the analysis of trade-offs and synergies only the three main independent datasets (habitat availability and nature experience, nutrient retention and quantitative recreational activities) were used separately to avoid any bias due to double counting. Simple graphical representation of areas with quantitative gain and loss within these ES categories due to the restoration measures was interpreted as a synergy (positive impact across ES categories) or trade-off (positive and negative impacts for different ES categories).
3 | RESULTS

3.1 | ES quality, quantity

3.1.1 | Regulating ES

Habitat availability in the system was predicted to change quantitatively as well as qualitatively due to the restoration measures. Change in habitat quality (diversity) was depicted using Principal Component Analysis (PCA) (Figure 2). For approximately one third of the modelled floodplain sections, a clear shift towards more dynamic and rheotopic conditions was predicted expressed as a dominance of indicator species for erosion/deposition patterns like gravel-breeding bird species and rheophilic fish including nase (Chondrostoma nasus) or asp (Aspius aspius). Side channels are in the present state often dominated by eurytopic species and only few specialized or protected species and habitats and thus, have relatively low relevance for conservation. Isolated floodplain sections dominated by stagnotopic species like Danube crested newt (Triturus dobrogicus), fish species like weatherfish (Misgurnus fossilis) or macrophyte communities of stagnant water bodies were widely preserved. Therefore, beta-diversity in the system was predicted to increase due to the restoration measures (Table 1). This predicted shift was also visible in the quantitative approach. The loss of habitat for protected stagnotopic and a few eurytopic species was much lower than the gain for rheotopic species due to the measures (Figure 2).

Our analysis predicted a clear positive impact of the proposed measures for nutrient retention. N and P retention was predicted to quantitatively increase in restored side channels (Figure 3, Quantity). Additionally, the quality (diversity, Figure 3 Quality, Table 1) of the system was predicted to increase. The floodplain system is actually dominated by internal processes (autochthonous material) and the measures would add side channel systems where allochthonous inputs from the river would dominate the nutrient cycling (Figure 3, Quality).

3.1.2 | Cultural ES

Overall, a positive qualitative diversifying effect on nature experience resulting from the restoration measures was predicted. The systems with opportunities for different recreational activities became more diverse (Figure 4, Table 1). Open erosive landscapes with flowing water as well as stagnant macrophyte rich waterbodies dominated by very different types of species were both available. For example, sites appropriate for recreational angling were in the present state dominated by eurytopic species like European catfish. The restoration measures were predicted to add a relevant number of sites with rheophilic communities (e.g., nase or asp), so that not only lake type but additionally river type sites were available in the floodplain for recreational fisheries after restoration. Various communities including several

![FIGURE 2](image-url)  
**FIGURE 2** Qualitative and quantitative assessment of the habitat provisioning ES. For the qualitative assessment the diversity of the floodplain sections along the hydrological gradient is shown summarizing probability of occurrence for all species using PCA (PCA 1, explains 41% of total variance). Predicted changes in the position along the hydrological gradient is shown in the histogram (upper graph), position of the different indicator species (see Appendix S1 for full names) characterizing the hydrological gradient is shown in the lower graph (Positions of the individual species are stretched and manipulated to make it readable). Quantity is calculated using a simple additive approach (MCDA-Multi-criteria decision analysis based) based on normalized sums of WUL for all species calculating overall gain, loss and total value following Funk et al., 2013
protected species with a high value as flagship species (e.g., kingfisher and gravel-breeding birds or European pond turtle) might be experienced after restoration.

Expected quantitative effects were in general low and involved few recreational activities (Figure 4, Table 1). In most cases (fishing, ice-skating and bathing), services were not directly affected due to the restoration measures, that is, neither a quantitative change of available water body length nor a loss of accessibility in the floodplain. For boating activities, a slight positive quantitative effect was found, obstacles in the systems (transversal check dams) that had to be passed on land in the status-quo would be removed and would be freely passable after the implementation of restoration measures. For walking and bicycle tracks, a negative quantitative effect was found. There would be a net loss of tracks due the removal of a tow-path along the main river that was used for walking and biking (Figure 4, Table 1).

3.2 | Multi-functionality of the floodplain

Summing all ES an increase in quality was found for the restoration scenario (Table 1). A clear positive effect was observed for the quantity of RES, nutrient retention and total habitat availability of the floodplain area. A negative effect was found for CES for walking and cycling due to the loss of path length. Consequently, in total there can be a strong increase in multi-functionality expected in the restoration scenario (positive total values in Table 1).

3.3 | Synergies and trade-offs

Simple graphical representation of areas with potential gain and loss of ES (Figure 5) showed a strong synergy (positive impact across ES categories) among habitat provisioning, RES and therefore, also nature

### TABLE 1 Change in the multi-functionality in the restoration scenario expressed as total values and change in quality (beta-diversity/Bray–Curtis dissimilarity index) and quantity (vector normalized (0-1) summed values for WUL, kg retention per year, and water body length for activities respectively) of the different ES indicators compared to the status quo

| ESS    | Indicator          | Qualitative/nature experience | Quantitative |
|--------|--------------------|-------------------------------|--------------|
|        | Status quo | Restoration | Change | Status quo | Restoration | Change |
| RES    | Nutrient retention | 0.14 | 0.21 | 0.07 | 0.17 | 0.93 | 0.76 |
|        | Habitat         | 0.20 | 0.23 | 0.03 | 0.54 | 0.64 | 0.11 |
|        | Mean            | 0.05 |         | 0.43 |
| CES    | Boating         | 0.14 | 0.14 | 0  | 0.70 | 0.71 | 0.01 |
|        | Bathing         | 0.13 | 0.16 | 0.03 | - | - | 0 |
|        | Ice skating      | 0.06 | 0.20 | 0.14 | - | - | 0 |
|        | Angling          | 0.13 | 0.17 | 0.04 | - | - | 0 |
|        | Walking/biking  | 0.15 | 0.21 | 0.06 | 0.77 | 0.64 | -0.13 |
|        | Mean            | 0.05 |         | -0.02 |
| Total  | RES + CES       | 0.10 |         | 0.41 |

Note: Results are summarized per ES category (mean) and in total (sum). Bold values mark an increase and bold italic values an decrease from the status quo to the restoration scenario.

### FIGURE 3 Qualitative and quantitative assessment of the nutrient retention ES. For the qualitative assessment the functional diversity of the floodplain sections along the hydrological gradient is shown, summarizing retention capacity for N and P using a PCA (PCA 1, explains 88% of total variance). Quantity is calculated based on a simple additive approach (MCDA based) using normalized sums of both values calculating overall gain, loss and total value following Funk et al., 2013
FIGURE 4  Qualitative and quantitative assessment of the CES, a: angling, b: boating; c: ice-skating; d: bathing and e: walking/cycling. For the qualitative assessment, that is, potential for nature experience, the diversity of the floodplain sections along the hydrological gradient is shown summarizing probability of occurrence for all species using PCA (PCA 1 see also Figure 2). Quantity was calculated using the total normalized length of water body or path length where the respective recreational opportunity is possible calculating overall gain, loss and total value following Funk et al., 2013.
experience across the whole floodplain system for the restoration scenario compared to the status quo. Locally, for one side channel system, trade-offs might be expected (negative impact of measures): On a few side channel sections, the loss of habitat (of the stagnotopic community) exceeded the gain of habitat (for the rheotopic community). In addition, a quantitative loss of CES (recreational opportunities) due to the reduction of infrastructure in the restoration scenario was observed.

4 | DISCUSSION AND CONCLUSION

4.1 | Restoration effects

There was a clear positive effect of the restoration measures on the RES predicted, qualitatively as well as quantitatively, and a strong positive qualitative effect on CES. A quantitative gain of habitat availability as well as a strong quantitative increase of nutrient retention was predicted. Allochthonous controlled systems have the ability to retain imported substances from the main river stem and may contribute to improve water quality (Natho et al., submitted). Previous studies in this area showed, that re-establishing regular surface water connection to the Danube River would increase nitrate removal capacity of the floodplain and reduce N₂O emissions by 50% (Welti et al., 2012). Habitat availability would increase quantitatively. Furthermore, there was a diversification predicted, as typical riverine habitats with their typical functions benefit from the measures. The now dominating rich stagnant water body types would widely remain. Previous studies close to this area showed similar results. Reconnecting parts of a floodplain system that are already closer to the main stem and leaving further distant and isolated systems unaffected was found to be the best compromise related to conservation targets in an urban floodplain system (Funk et al., 2013). It was also ranked best across different stakeholder groups including national park authorities, nature conservation NGOs, adjacent municipalities and governmental organizations for the urban floodplain (Sanon et al., 2012). Our results are in line with other wetland studies. Meli et al. (2014) reviewed 70 ecological wetland restoration studies and found a recovery of biodiversity together with provisioning, regulating and supporting ES.

The proposed measures are in line with the restoration as well as conservation targets of the national park (NPDA, 2019). Fractions of water bodies with permanently flowing conditions and rheotopic communities will increase from approx. 1% coverage in the current state to approx. one third in the restoration scenario. It is therefore significantly closer to the historic reference state where approx. Two thirds of the side channels had permanently flowing conditions (Hohensinner, Jungwirth, Muhar, & Habersack, 2005). This also directly links to the targets of the EU Water Framework Directive (2000/60/EC; WFD) for that river type as the system comes significantly closer to the reference state due to the restoration measures. Furthermore, as the DANP is part of the Natura 2000 network, targets of the Habitats Directive and Birds Directive are of great importance for the system. In this respect, the planned restoration measures would be of particular importance for the targeted listed endangered species of the rheotopic community (e.g., protected rheophilic species and erosion/deposition dependent species of water.
birds). Overall, this community does not reach the targeted “favourable conservation status” in the present state (https://www.eea.europa.eu/data-and-maps/data/natura-9), pan-European database by the European Environment Agency (EEA), database information from 2017 was used), but habitat availability will increase in the restoration scenario.

4.2 | Synergies and trade-offs

The two RES evaluated in detail, habitat provisioning and nutrient retention, showed a clear synergistic effect for the proposed restoration measures. Areas with a net gain of habitat availability would be also most relevant for the increase of nutrient retention. For the restoration scenario there would be a gradient expected, ranging from dynamic water bodies with high nutrient retention capacity dominated by rheotropic species to stagnant systems with no relevance for nutrient retention dominated by a stagnotrophic community. This is in concordance with the findings that both ecosystem functions (Hein et al., 2003; Noe et al., 2019; Tockner et al., 1999) as well as biotic communities (e.g., Desjonquères et al., 2018; Leigh & Sheldon, 2009; Paillex et al., 2013; Reckendorfer et al., 2006) change along the hydrological gradient in floodplain systems. A large-scale 10-year experiment at the Olentangy River Wetland Research Park in Ohio, USA, demonstrated that restoration of hydrological dynamics decreased greenhouse gas emissions, organic matter accumulation and increased nutrient retention as well as biodiversity (Mitsch et al., 2008), which is in line with the modelling results of the presented study.

A strong synergy would consequently also be expected with nature-based recreational activities. Opportunities for nature experiences would increase significantly, as the heterogeneity of habitats and species that can be experienced during a visit would strongly increase (see also Richards et al., 2018; Stepniawska & Sobczak, 2017). Important flagship species of the national park and floodplains in general would be conserved or fostered. This includes fostering attractive flagship bird species for dynamic floodplains sections like European Kingfisher (Alcedo atthis, Heneberg, 2013) or Little Ringed Plover (Charadrius dubius, Schmidt et al., 2015). On the other end of the hydrological gradient, the conservation of important flagship species representative for stagnant floodplain water bodies like the European pond turtle (Emys orbicularis, Puky, Gémesi, & Schád, 2004) or the Danube Crested Newt (Triturus dobrogicus, Edgar & Bird, 2006) both a “symbol of wetland conservation” would be guaranteed as the stagnant habitat type is preserved in the system.

Few trade-offs were recorded. Locally restricted, gain of nutrient retention capacity, dynamic habitats and gains for nature experience conflict with a loss of quantitative opportunities for selected recreational activities. There was a weak local trade-off between the qualitative effect on nature experience and quantitative availability of space for recreational activities, such as area or path length for recreational activities. In particular, activities that use the system simply as a “sporting area” and do not seek a rich nature experience for example, jogging, walking or mountain biking would locally be negatively impacted. This is in concordance with findings from Rall, Bieling, Zytnyska, & Haase, (2017) and Bieling and Pleninger (2013) who both found two contrasting ES bundles, one reflecting direct recreational and social opportunities and the other qualitative, immaterial nature experience focused services.

Within the ES category of habitat provisioning we also found a trade-off between the stagnotrophic and rheotropic community, which is already well known in floodplain systems (Schiemer et al. 2007, Funk et al., 2013, Sanon et al., 2012). In our study there would only be a very weak and localized effect expected as most of the sites selected for reconnection are already partially connected and mainly dominated by eurytopic species (see also Janauer, Schmidt-Mumm, & Schmidt, 2010; Reckendorfer et al., 2006; Schomaker & Wolter, 2011; Skern, Zweimüller, & Schiemer, 2010). Those species are rarely targets of conservation efforts since they are widely distributed and not threatened (e.g., Reckendorfer et al., 2006; Schiemer & Waidbacher, 1992).

4.3 | Restoring multi-functionality

Overall, there would be a clear total gain in the multi-functionality of the system’s habitat gain for biodiversity; RES and therefore, opportunities for nature experiences would increase. This is in concordance with previous findings and assumptions that restoration efforts in general (Benayas et al., 2009) and specifically reconnections of floodplains (Funk et al., 2019; Schindler et al., 2014) increase and restore the multi-functionality related to biodiversity and ES. Heterogeneity in floodplain hydrology was found to significantly increase biodiversity (e.g., Amoros & Bornette, 2002; Chaparro, Horváth, O’Farrell, Ptacnik, & Hein, 2018; Dittrich, Dias, Bonecker, Lanskac-Tôha, & Padial, 2016; Schomaker & Wolter, 2011; Zilli & Marchese, 2011) and more recently it was shown that this heterogeneity can also help to balance provision of multiple ES (Richards et al., 2018). In human altered floodplain systems, achieving this heterogeneity and restoring the multi-functionality requires a detailed planning of “compromise” scenarios including the analysis of trade-offs and synergies (Rouquette et al., 2011). In our case study system this would be achieved with a spatial differentiation where areas with high ES value in the status quo (rich stagnotrophic community and/or high recreational value) are conserved at that status and waterbodies with relatively low ecosystem value in the status quo (eurytopic community) would be targets for restoring the natural riverine functions and the rheotrophic community.

5 | CONCLUSIONS AND IMPLICATIONS

With our innovative approach we are able to quantitatively as well as qualitatively (using a dissimilarity approach) evaluate the potential effect of restoration measures on ES and their multi-functionality in one comprehensive study for large river floodplain systems. We found strong synergies at the floodplain scale and weak localized trade-offs between the quantitative and qualitative components. Although
restoration measures may lead to a locally restricted quantitative loss of recreational opportunities, the strong increase in functional and biotic diversity as well as diversification of opportunities for nature experiences targeted by the restoration measures was modelled to prevail in the investigated floodplain system.

Further, localizing areas with potential trade-offs give the opportunity for managers to adjust and fine tune developed restoration plans to avoid local negative effects of the restoration measures. As the trade-offs between stagnotopic and rheotopic communities as well as between nature experience and quantitative availability of space for recreation, would be locally restricted, no negative large-scale effect on communities would be expected. However, a detailed analysis and monitoring of the concerned biotic communities should be taken in consideration, especially if other developments such as climate change or invasive alien species alter the predicted outcomes.

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DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available from the corresponding author, AF, upon reasonable request.

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