Integrated planning framework for successful river restoration projects: upscaling lessons learnt from European case studies

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ABSTRACT

Despite considerable investment in river restoration projects, there is still limited information on the efficacy and success of river restoration activities. One of the main reasons is poor or improper project design, resulting in common problems such as: not addressing the root cause of habitat degradation; not establishing reference conditions, benchmarks and not defining endpoints against which to measure success; inappropriate uses of common restoration techniques because of lack of pre-planning; and inadequate monitoring or appraisal of restoration projects. In this paper peer-reviewed and grey literature and a large database of existing case studies were reviewed to identify the prevailing challenges river managers face when planning and developing river restoration projects. To overcome these current challenges an integrated project planning framework has been developed that incorporates adaptive management and project management techniques. It encapsulates key concepts and decision support tools to advance the existing sequence of project identification, project formulation, project implementation and post-project monitoring to incorporate multidisciplinary decision making to meet specific environmental and socio-economic objectives. The proposed river restoration project planning framework is adaptable and can therefore be applied to any project development scenario locally, regionally or internationally.

Keywords: river restoration, project planning, adaptive management, success, evaluation, monitoring

1. INTRODUCTION

Since the late 1980s, there has been a rapid expansion in river restoration projects in industrialised countries in an effort to improve degraded habitats and improve their ecological well-being. Despite considerable investment in these projects, there is limited information on the efficacy and success of river restoration activities (Bernhardt *et al*. 2005; Roni *et al*. 2008; Roni & Beechie, 2013). The success or failure, and underlying reasons for either, are rarely evaluated in most river restoration projects (Kail *et al*. 2015). Consequently, little is known about their effectiveness resulting in many restoration projects failing or falling short of their objectives (Bernhardt *et al*. 2007); if such objectives have been established prior to the project implementation.

Planning is key to project management success, but, despite there being numerous guidelines available for river restoration project planning (e.g. Cowx & Welcomme, 1998; Hammond *et al*. 2011; Roni & Beechie, 2013; Gurnell *et al*. 2016), they are not readily applied by river managers and practitioners (Roni & Beechie, 2013). Globally, it is reported that there are limitations, or even disregard, within the planning stages of river restoration that subsequently restrict or prevent project evaluation (Montgomery & Buffington, 1997; Doyle *et al*. 1999; Boon & Raven, 2012; Jansson *et al*. 2007; Roni & Beechie, 2013). These limitations need to be understood and resolved to improve guidance that will further benefit existing and future restoration efforts at a local and catchment scale.

The primary goal of this paper is to present an integrated project planning framework for river restoration that will help practitioners and river manager address the common challenges when designing and implementing the most appropriate river restoration project successfully. The objectives of the paper were to critically review peer-reviewed and grey literature to identify the prevailing processes and challenges river managers face when planning and developing river restoration projects. Further, the objectives of global river restoration projects of European-funded LIFE & INTERREG projects in addition to a large database of existing European river restoration case studies collated for the European Union (EU) REFORM project - Restoring rivers FOR effective catchment Management (http://reformrivers.eu/) were evaluated against outputs/outcomes. The conclusions from the literature review and the analysis of existing case studies created a comprehensive baseline of characteristics and challenges in determining river restoration success or failure and were used to develop the proposed framework.

2. ANALYSIS OF EXISTING RESTORATION PROJECTS

2.1 Literature review

When planning and implementing river restoration projects, managers are met with perpetual challenges that often lead to unexpected or unsuccessful outcomes or simply do not have sufficient information on existing projects on which to base the project design (Bernhardt *et al*. 2005; Roni & Beechie, 2013). To identify these fundamental challenges, relevant literature published between 1971-2013 was located through a targeted ISI Web of Knowledge search. The following key terms and Boolean links were used: (Topic = (river* OR floodplain OR stream OR riparian) AND Topic = (restor* OR rehab* OR mitig* OR conserv*) AND Topic = (goal* OR objective* OR endpoint* OR benchmark* OR success*)). A total of 663 publications were identified and reviewed to identify the most common challenges or reasons for failure of river restoration projects. Poor or improper restoration project planning due to inadequate guidance (Bernhard *et al*. 2007) was found to be the foremost constraint that sequentially led to a number of issues:

- Absence of multidisciplinary approaches to restoration planning (environmental, socio-economic and engineering) (Doyle *et al*. 1999);
- Not addressing or lack of understanding of the root cause of habitat degradation (Boon & Raven, 2012; Roni & Beechie, 2013);
- Focus on single rivers and small scale restoration actions (failure to plan at a catchment scale and include upstream and downstream processes and connectivity issues) (Jansson *et al*. 2007);
- Not establishing reference condition benchmarks and success evaluation endpoints against which to measure success (Roni *et al*. 2002; Bernhardt *et al*. 2005, 2007; Roni *et al*. 2008);
- Lack of, or an inconsistent, approaches to sequence or prioritise projects (Roni & Beechie, 2013);
- Inappropriate use of common river restoration techniques because of lack of pre-planning (one size fits all) (Montgomery & Buffington, 1997);
- Failure to get adequate financial and technical support from public and private organizations;

- Cost/benefit analyses overlooked or poor documentation of project costings (costs generally grouped at 'total' cost for whole project) (Brouwer *et al*. 2009; Shamier *et al*. 2013);
- Inadequate monitoring or appraisal of outcomes of river restoration projects to determine project effectiveness (Cowx, 1994; Downs & Kondolf, 2002; Wohl *et al*. 2005; Rumps *et al*. 2007);
- Paucity of restoration projects that measure success in terms of hydrogeomorphological and ecological outcomes (Hobbs & Harris, 2001);

Advancing from the literature review, 952 European case studies were reviewed to ascertain the key challenges when determining river restoration project success or reasons for success or failure. Two sources of information were used to compile this information: 1) the EU REFORM case study meta-database; and 2) European-funded LIFE & INTERREG programmes.

2.2 EU REFORM database

The EU REFORM project compiled a meta-database from peer-review and grey literature to create a resource base of existing knowledge. From this database, 671 European case studies were reviewed to determine ecological outcomes (successful, unclear, no information, not monitored or failed) based on measured improvements to biological (e.g. fish, invertebrates and instream vegetation), morphological (river process and function, e.g. sediment deposition and remeandering) and physio-chemical (water quality including parameters such as dissolved oxygen, pH, nitrate and total dissolved solid) features. Only a small number of case studies reported ecological success (9%) or failure (1%): many studies were either unclear (5%) in their findings, the restoration works were not monitored (9%) or no information (77%) on the outcome was provided. The same pattern was found when subdividing ecological success rate into biological, morphological and physio-chemical success (17%, 8%, 3%), failure (1%, 0%, 0%), unclear (8%, 5%, 1%), not monitored (4%, 9%, 14%) or no information (70%, 78%, 82%), respectively (Figure 1). This interrogation of the EU meta-database supports the conclusions expressed elsewhere (Downs & Kondolf, 2002; Bernhardt *et al*. 2005; Roni *et al*. 2008; Cowx *et al*. 2013; Roni & Beechie, 2013) that success or failure of habitat restoration projects is often not evaluated and therefore little is known about their effectiveness. Whilst the underlying reasons for the absence of project outcomes are complex, they are often attributed to limited guidance for river restoration planning and subsequent methods of evaluation of project success.

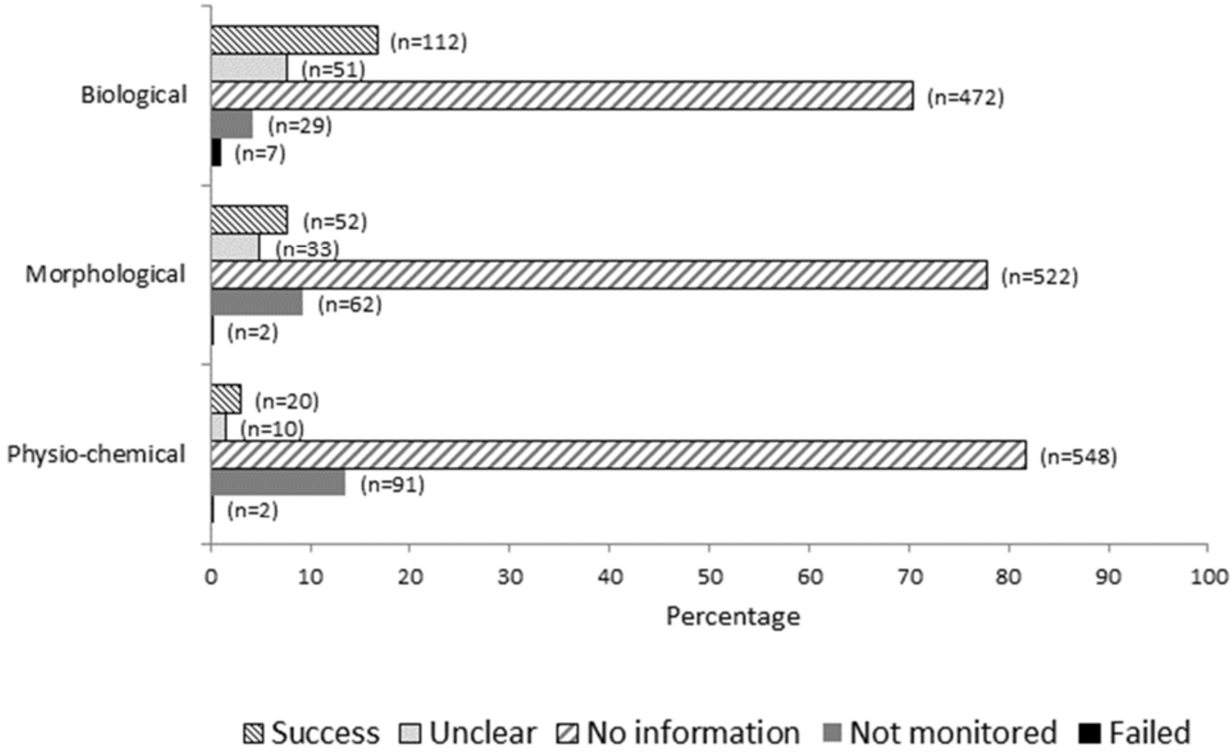

Figure 1. Biological, morphological and physio-chemical success rates for 671 European case studies from the EU REFORM meta-database.

2.3 EU LIFE & INTERREG projects

To interrogate further the underlying causes for the failure to assess the outcomes of restoration activities, an online search of 281 EU LIFE & INTERREG projects was carried out. LIFE & INTERREG are European funding programmes aimed at assisting the implementation of EU Directives. LIFE Nature and LIFE Environment are both the main strands of the EU funding programme to preserve the environment (European Commission Environment – LIFE Programme, 2011) and were established to support the implementation of EU environmental policy. LIFE Environment focuses more on issues such as river habitat conservation, species conservation and river basin management while LIFE Nature supports projects that mainly contribute to the implementation of the EU Birds Directive (79/409/EEC) and Habitats Directive (92/43/EEC) through the development of the NATURA 2000 network. The EU

INTERREG programme aims to stimulate cooperation between regions and with regards EU water policy, INTERREG aims to assist project managers and authorities in implementing the EU Water Framework Directive (WFD (2000/60/EC)), the EU Flood Directive (FD (2007/60/EC)) or promote species or habitat action plans that set management priorities for NATURA 2000 areas across Europe. As such, these are major European initiatives that should be underpinned by comprehensive project proposals and defined project outcomes.

The review of the INTERREG & LIFE funded river restoration projects identified the following key findings:

- Project objectives were formulated from different perspectives, whether this be environmental or socio-economic. INTERREG project objectives are more or less equally distributed among flood management (24%), integrated river basin management (31%) and river and floodplain restoration (25%) with other objectives less important (Table 1). LIFE projects implemented restoration measures mainly to improve river and floodplain habitats (67%) or species conservation and management (30%) (Table 1).
- Although most projects were implemented within the frame of a wider approach, such as a national conservation strategy or river basin management plan (e.g. LIFE Skjern project (Andersen, 2005) & the Conservation of Atlantic Salmon in Scotland project (CASS, 2017)), 'restoration' success was rather difficult to evaluate, even with well-developed ecological monitoring, because most projects did not establish measurable success criteria.

Table 1. Global objectives of INTERREG & LIFE funded river restoration projects.

Global objectives	**INTERREG**		**LIFE**	
	n	**%**	**n**	**%**
Flood management	20	24	2	1
Integrated River Basin Management	26	31	1	1
River and floodplain restoration	21	25	132	67
Species conservation and management	14	16	59	30
Water quality improvement	4	5	2	1

Further interrogation of the LIFE projects that had specific ecological goals and objectives targeting river and floodplain restoration, revealed 41% of projects implemented a large range of measures aimed at improving multiple ecosystem components (Table 2). Additionally, 20% of projects carried out river restoration measures aimed at improvement of floodplains/off-channel habitats or lateral connectivity and 15% were for riparian zone improvement (Table 2). Regarding species conservation and management objectives, the projects mainly targeted fish species enhancement (56%) and mollusc enhancement (16%) (Table 2).

Table 2. LIFE project specific objectives of river and floodplain restoration and species conservation and management objectives.

Objective: River & floodplain restoration			**Objective: Species conservation and management**		
Specific objective	**n**	**%**	**Specific objective**	**n**	**%**
Lateral connectivity improvement	27	20	Bird species enhancement	4	5
Flow dynamic improvement	7	5	Crayfish species enhancement	1	1
In-channel & substrate improvement	6	4	Fish species enhancement	43	56
Longitudinal connectivity improvement	8	6	Invasive species management	3	4
Network development	5	4	Mammal species enhancement	6	8
Riparian zone improvement	20	15	Mollusc species enhancement	12	16
River bed depth/width variation improvement	1	1	Multiple	8	10
Sediment flow quantity improvement	2	1			
Water flow quantity improvement	4	3			
Multiple	57	41			

The review of LIFE & INTERREG projects with their main or secondary objectives to improve river habitats and/or enhance species identified:

- National policy objectives play a key role while undertaking a river restoration project;

- When the main aim was to counteract flooding (n = 22), only 27% of projects included ecological outlooks but these were not as well developed as the flood management perspectives, thus preventing full evaluation of pre-restoration ecological status or implementation of robust post-restoration monitoring to evaluate outcomes;
- Application of specific ecological objectives and evaluation of ecological status of the ecosystem before and after restoration was limited. Most (96%) of projects were constrained by 2 factors: timing and/or funding. For example, the AVON project objectives were to restore the watercourse habitat and conditions for associated species at priority sites in addition to demonstrating innovative restoration techniques within the River Avon SAC in the UK (Hamersley & Wheeldon, 2009). In this project pre-restoration ecosystem evaluation was carried out, but the timelines of the project made it problematic to collect long-term pre-data, as the project only received funding six months before the official project start. In the case of the LIFE project implemented along the Lippe River (www.life-lippeaue.de) in Germany to introduce a flood retention area and protect threatened species, no funding was made available to monitor project success either from the EU or from the German state, and therefore monitoring the success in achieving the project outputs was not technically feasible;
- Difficulty in setting meaningful biological targets when the monitoring only lasts for two years in the frame of LIFE or INTERREG funded projects (e.g. due to the complex life cycle of the freshwater mussel, it would take 5-10 years (at least) to assess the conservation impact of the implemented actions according to the project manager of the LIFE project 'Freshwater Pearl Mussel and its habitats in Sweden (www.wwf.se/fpm).

Specific project objectives that consider functional aspects of the ecosystem are often lacking due to the absence of well-defined project objectives, but are necessary to advance decisions based largely on subjective judgements to those supported by scientific evidence. A key issue is that project objectives are usually defined by institutional, regional and national policy with a more general overarching goals, whereas project managers should also make sure they are project specific and quantitative to compare results against target objectives enabling project success to be evaluated. For example, the WFD promotes 'good ecological status or potential' and many restoration projects use this target as their main project objective. This, however, describes the extent to which ecological quality deviates from what would be expected under near natural conditions and should not necessarily be the project objective or end point. Indeed it is often not a valid end point because there is huge variation in ecosystem quality within each WFD quality category.

The analysis of the literature, and EU LIFE and INTERREG projects highlighted the issues with determining project effectiveness if well-defined, project-specific objectives have not been formulated and quantified. There is also a lack of project planning, underpinning the formulation, design, implementation and evaluation of projects, highlighting the need to embrace project planning and evaluation tools in river restoration (or an environmental improvement) project design. This review is justification for the development of the project planning framework developed in Section 3, which is based heavily on overcoming the limitations summarised in this section. It is not the intention of the framework to reduce project failure directly, but it strives to improve guidance and techniques for successful river restoration management. The framework meets these needs by providing a step-by-step guide to river restoration planning and provides tools to assess stream and watershed conditions, to identify factors degrading aquatic habitats to establish well-defined project objectives, and to set measurable targets for restoration to evaluate the effectiveness of the restoration.

3. INTEGRATED PROJECT PLANNING FRAMEWORK

The integrated project planning framework (Figure 2) will help address the common challenges facing the design of the most appropriate river restoration project to achieve local and catchment wide benefits in a cost-effective manner. The framework incorporates project management techniques to advance key concepts and decision support tools. It advances the existing sequence of project identification, project formulation, project implementation and post-project monitoring to incorporate multidisciplinary decision making to meet specific environmental and socio-economic objectives. The framework is not intended to be a rigid blue-print project, instead it is an adaptive procedure that should be modified to account for new information and localised changes as the project progresses. In this context, adaptive management plays a key role throughout the whole planning process for river restoration, allowing for decisions to be made and actions to be implemented even when uncertainty is high due to a complex system and lack of existing knowledge on similar systems.

Effective river restoration management requires collaboration between disciplinary practitioners (e.g. hydrologist, biologist, ecologist, geologist, economist and sociologist) and interaction with policy makers and local stakeholder communities to distinguish between the social, economic and environmental requirements of the foreseen project (Letcher & Giupponi, 2005). This will enable suitable 'goals' and 'objectives' to be established for restoring the system to an acceptable [measureable] state, ultimately leading to a reinstated, functioning river ecosystem (Cowx, 1994; Kondolf *et al*. 2006; England *et al*. 2007). The framework is characterised by a number of carefully planned phases that are interlinked, such as PDCA (plan, do, check and act) and the participation and consultation ladder that accounts for the needs and aspirations of the various stakeholders and relate overall to national policies and sector plans (Figure 2). The emphasis is on adaptive management, developing restoration projects in a rational way supported by economic and sectoral analyses to understand the potential of a particular action, thus giving the capacity to minimise conflict and optimise multiple win scenarios as the needs and aspirations of all resource users are integrated into the framework. Furthermore the framework applies a strategy that identifies high priority projects that appear suitable for development to support a coherent restoration strategy that meets both environmental policy and cross-sectoral objectives in a cost effective, socially acceptable manner. In Europe for example, the framework will help halt the loss of biodiversity by conserving habitat and species of European importance by supporting the delivery of the EU WFD 'good ecological status or potential' and the EU Biodiversity strategy, specifically with the delivery of Target 1 – protected species and habitats and Target 2 – to maintain and restore ecosystems and their services (European Commission, 2017).

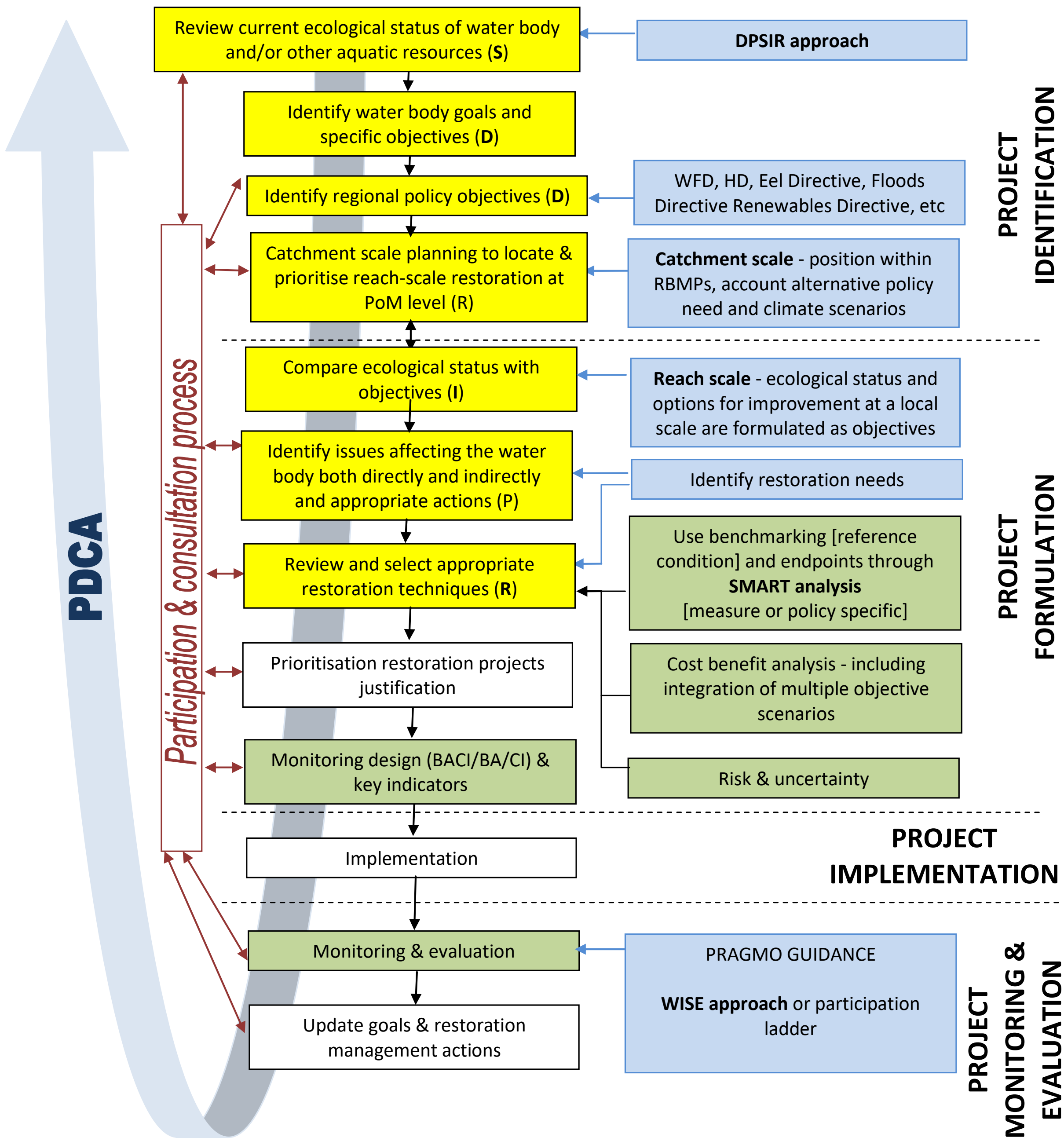

Figure 2. Integrated project planning framework for restoration projects, yellow coloured boxes represent steps in the DPSIR approach to management intervention. FIGURE TO BE IN COLOUR

3.1 Project identification

Project identification is the stage at which the initial restoration project proposal is conceived and formulated, and may be divided into two fundamental components: 1) current status of the water body to identify water body goals and specific objectives and 2) regional and national policy objectives. The first step provides an understanding of the current status of the biota, hydrogeomorphology, ecosystem functioning and ecosystem services to establish a baseline against which to develop any restoration project. This stage should identify the purpose and need for restoration through monitoring catchment and water body status, the basic information required includes, but is not exclusive to:

- river characterisation, understanding the river type, process and function in addition to the historical geography and landscape topography (e.g., the hierarchical, multi-scale, hydromorphological framework designed for operational use in the context of river management; Rinaldi *et al*. 2016; Gonzales del Tanago *et al*. 2016);
- sector pressures such as urban, agricultural, industrial and renewable energy development (and associated water quality issues) (e.g., DPSIR framework; Angelopoulos *et al*. 2015);
- indicators of physical habitat modification and geomorphological alteration (Friberg *et al*. 2016a);
- hydrology, including modifications to the flow regime, abstraction and other water uses;
- flood defence;
- barriers (dams, weirs)
- fisheries, recreation and conservation (Cowx & Welcomme, 1998);
- water quality.

More specifically monitoring water body status will evaluate watershed processes, current river health and ecological status to (Beechie *et al*. 2008, 2009; England & Gurnell, 2016; Mosselman *et al*. 2015; Rinaldi *et al*. 2016; Gurnell *et al*. 2016): (1) identify how habitats have changed and altered biota; (2) identify the causes of habitat changes; (3) identify restoration actions needed to address those causes; and (4) acknowledge social, economic and land use constraints. This will establish a suitable baseline against which suitable 'goals' and 'objectives' can be established for restoring the system to an acceptable state, ultimately leading to a self-sustaining river ecosystem (Cowx, 1994; Kondolf *et al*. 2006; England *et al*. 2007).

The aims and objectives of government policy also provide input into the framework that restoration projects must fit to ensure that remediation actions can proceed in a rational way commensurate with policy objectives. This ensures restoration projects are in the context of national and regional policy issues and consider the overall justification for the project, the likely target groups and impact beneficiaries, as well as those who might be adversely affected. In addition, the key external factors influencing the likely success or failure of the project can be integrated into the decision framework. For example, the aims of restoration activities in Europe are influenced by a plethora of EU Directives and national government policies, such as WFD, Habitats Directive and Floods Directive. The key to formulating suitable objectives to improve water body status is the assessment of the interrelationships (nested-DPSIR see below) between human activities and environmental factors that drive the ecosystem functioning and provision of services to meet specific environmental and socio-economic objectives.

3.1.1 Driver-Pressure-State-Impact-Response

The DPSIR (Driver - Pressures – State - Impact - Response) framework is a holistic approach that identifies key relationships between society and the environment at single level interactions and can be up-scaled to identify suitable synergistic opportunities (nested-DPSIR, Atkins *et al*. 2011) for river restoration that provide benefits at the catchment scale whilst being fine-tuned with European directives (Mosselman *et al*. 2015). Drivers are the key demands on inland waters by society, such as agricultural and urban land use, flood protection, inland navigation and renewable energy (e.g. hydropower). These drivers are responsible for pressures (e.g. abstraction, embankment, habitat fragmentation, flow regulation) that cause biological and abiotic state changes and further impacts within the river ecosystem. For example, flood protection (Driver) will result in channelisation (Pressure) which steepens the banks (Status change) and results in a loss of aquatic vegetation and habitat for fish (Impact). Response is the application of river restoration measures to mitigate impacts on ecosystem functioning to prevent deterioration or improve state changes in the environment. The nested-DPSIR (Driver - Pressures – State - Impact - Response) framework is a conceptual tool that allows this single level interaction to be up-scaled because it identifies key relationships and conflicting interests between society and the environment and encourages the decision-maker to think about the challenges at a larger scale, across multiple sectors (Atkins *et al*. 2011). Externalities (factors that are out with the natural functional characteristics of the ecosystem) that impact on the ecological status and responses to these measures are also considered, such as climate change effects and alien invasive species (Angelopoulos *et al*. 2015). It is critical that full consultation with stakeholders and those likely to be affected by the restoration measures is undertaken, and the DPSIR framework ensures the needs and aspirations of all are included in the decision making procedure.

3.1.2 Catchment to reach scale

The freshwater reaches of riverine ecosystems are intrinsically linked, and have a natural habitat continuum between the river and the landscape (Thorp *et al*., 2006). Broad-scale processes and interactions between adjoining ecosystems consisting of a set of hierarchically nested physical, chemical and biological processes operating at widely varying space and timescales add further complexity (Hermoso *et al*. 2012). As a consequence, it is difficult to improve a small reach of river by simply using remediation actions at a local level; furthermore impacts in one place may be the result of events or management decisions elsewhere (Findlay & Taylor, 2000). Catchment-scale planning provides information on river characterisation, river condition and restoration potential, all of which underpin the decisions made to select restoration measures and has increasing emphasis in Europe, as part of the WFD Programme of Measures (PoM). Fortunately, potential benefits of implementing river restoration and conservation at a catchment-scale are being increasingly recognized as an essential component of future restorative practices (Hodder *et al*. 2010; Friberg *et al*. 2016b). The end result of project identification is to locate and prioritise reach-scale restoration projects, some of which will combine several rehabilitation measures, in an attempt to ensure smaller scale projects work towards a catchment approach.

The integrated project planning framework is designed to be flexible, to plan for both large- and small-scale projects and is underpinned by the simpler project planning cycle where adaptive management ensures knowledge is acquired by experience (Figure 3). The project cycle allows for smaller projects, and in some instances pilot studies, to be planned at a local scale whilst still feeding in to a large scale reach or catchment planning. The idea is that several project planning cycles with different aims and objectives can be run at the same time, whilst all contributing to an overall more general goal. The project planning cycle still follows the same structure as the project planning framework (project formulation; financing; project implementation; post project monitoring; post project evaluation and adjustment or maintenance) but is a more simplified approach for small scale projects. Conversely, larger projects that have an overarching aim can be broken down into more manageable sub-projects with specific aims that feed into a larger framework.

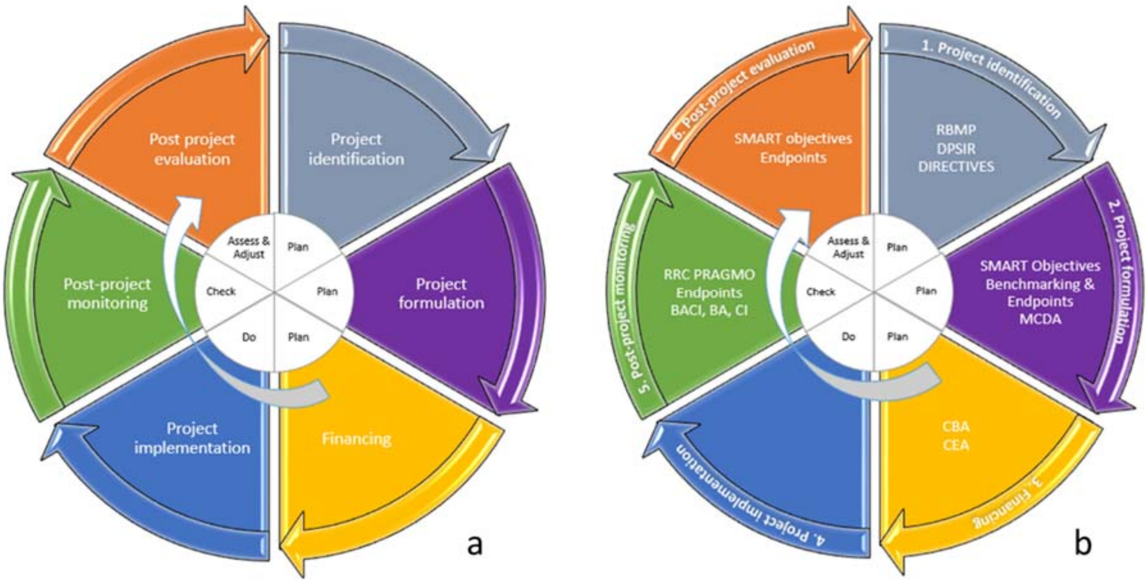

Figure 3. Project planning cycle at a project scale. (A) Six stages for restoration project planning: (1) project formulation; (2) financing; (3) project implementation; (4) post project monitoring; (5) post project evaluation and (6) adjustment or maintenance. (B) An example of the tools needed at each stage (Friberg *et al*. 2016). FIGURE TO BE IN COLOUR

The integrated planning framework (Figure 2) is suitable for larger projects with numerous objectives; the PDCA feedback loop provides managers with the ability to account for uncertainty through the evaluation of outcomes and is facilitated by an improved understanding of the efficiency of rehabilitation measures. This will enable all managers to be responsive to unforeseen circumstances and adjust objectives, restoration measures and timeframes accordingly throughout the project, especially as knowledge increases.

3.1.3 Participation and consultation process

As part of the appraisal of a prospective restoration project, there is a requirement for broad consultation through the planning and implementation phases to ensure all stakeholders have a say in the development and engage with the project. As part of this consultation, an evaluation of the current and future conflicts, both real and perceived, between the project activities and outcomes and other user groups should also be made. This can be achieved using matrix analyses such as those used in environmental impact assessments. Coos Watershed Association

(2006) is a good example of how matrix analysis can be used in the participation and consultation process for river restoration. In summary, a set of potential habitat restoration methods were listed, weighted and scored for two sets of criteria; 1) environmental and 2) socio-economic based on the estimated effect that an action would have on current conditions (Coos Watershed association, 2006). These categories and their relationship to each other are what determined the priority level of each action.

3.2 Project formulation

Project formulation shifts the emphasis from the suitability and feasibility of the project with regards to the status of the aquatic ecosystem and the overall regional and national policy objectives to the acceptability of the project and the desired outcomes at a more local level. The identified project(s) now comes under more intensive scrutiny by the project planning team. Earlier estimates, and qualitative indicators laid down in the identification phase, will be refined and examined in detail through a number of steps (Figure 2):

- comparing ecological status (baseline) with expected outcomes (endpoints) to define objectives;
- identifying issues affecting the water body both directly and indirectly and appropriate actions;
- review and select appropriate restoration techniques;
- prioritisation of restoration project and justification;
- monitoring design.

The ecological status of a river and options for improvement at a reach scale are formulated as objectives that feed in to overarching regional or national objectives. Developing project objectives is a vital stage in project planning and it is essential that many of the steps discussed in the project identification phase feed in to the decision process. It is advised that SMART (Specific, Measurable, Attainable, Relevant and Timely) objectives are formulated in addition to river restoration benchmarks and endpoints for all projects, this is discussed in the following sections.

3.2.1 SMART objectives

A useful framework for establishing objectives is the SMART approach (Skidmore *et al*. 2013 *in* Roni & Beechie, 2013). This should encompass establishing target conditions based on an understanding of what is technically feasible, socially acceptable and economically viable. Setting SMART objectives enables evaluation of the overall project effectiveness through application of objectives that test against outcomes. It also requires collaboration between disciplines (e.g. hydrologist, biologist, ecologist, geologist, economist, sociologist) and interaction with policy makers and the local, stakeholder community to distinguish between the social, economic and environmental requirements of the foreseen project (Letcher & Giupponi, 2005).

3.2.2 Benchmarks and endpoints

Goals and objectives need to be set at multiple stages of the restoration process, and there are multiple steps within each stage, but the initial step is to identify benchmarks and endpoints against which to measure performance. Benchmarks are measurable targets for restoring degraded sections of river within the same river catchment. Endpoints are target levels of restoration, whether this is an ecological (to restore a level of function/species), social (delivery of services to society) or physico-chemical (river morphology, water quality) endpoint. It is imperative that endpoints accompany benchmarks in the planning process and are linked closely to project objectives to guarantee the prospect of measuring success, especially because endpoints are feasible targets for river restoration. Key questions to consider when formulating benchmarks and endpoints include:

1. Is the main aim of the project to improve the physical processes of the river or to increase biological diversity in defined areas?
2. If the focus is to increase river forms and processes, what will be the benefit for the ecology (specific fauna and flora and, where appropriate, part(s) of life cycle(s))?
3. If the focus is to increase ecological (habitat) diversity for a range of fauna and/or flora, which parts of the life cycle are being targeted to restore and what physical river features need to be enhanced to support this goal?
4. Have quantitative or qualitative indicators been established that provide a simple and reliable means to measure achievement, reveal the changes connected to an intervention, or help assess the performance of an organization against the stated target? Such performance indicators are used to assess and measure the progress related to an expected result or an aspect of it, and to identify to what extent beneficiaries/target groups have been reached.

Overall, objectives should work towards ecological benefits whilst enhancing understanding of how communities respond to changes in physical habitat over time, for example, taking into account the needs of individual fish species, size classes and guild structure, to recognise the 'missing' habitat and identify the habitat improvement measure(s) needed.

This mechanism of identifying benchmarks and endpoints to measure performance against clearly defined goals should ensure effective use of resources and increase the likelihood of restoration success (Woolsey *et al*. 2007). There are a handful of positive exceptions where baseline conditions, expectations and evaluation have been well documented, e.g. the Rhône River (Lamouroux *et al*. 2015), the Danube River (Schiemer *et al*. 1999) and the Kissimmee River (Koebel & Bousquin, 2014). In particular, the Kissimmee project defined expectations based on nine abiotic responses for hydrology, geomorphology and water quality, five expectations related to changes in plant communities in the river channel and floodplain, whilst six related to invertebrate, amphibian and reptile communities and a further five expectations described the anticipated changes in fish and bird communities (Anderson *et al*. 2005). These are all quantified improvements that can be measured by continuous monitoring of the system over time.

3.2.3 Review and select appropriate restoration techniques

There is likely to be more than one option (measure) or a combination of measures to resolve an issue, thus the advantages and disadvantages of each should be considered and their inter-linkages explored. In addition, this assessment should include the feasibility of achieving the outcome of the stated option both from a technical as well as a financial perspective, but also to identify potential win-win scenarios. If necessary, alternative solutions may need to be sought, especially where there are budgetary constraints. Consequently, the plans should be formulated on local issues but take a wider perspective at the catchment and regional/national levels (Friberg *et al*. 2016b). This assessment can be used in an attempt to resolve the problems by aggregating the relevant aspects into a multi-functional and multi-use plan by identifying institutions and stakeholders responsible for implementing certain actions.

3.2.4 Cost-benefit analysis

Once the management plan has been formulated, and adequate consultation has been made with Government departments, institutions, user-groups, industry and the public, it should be possible to draw up action plans for the future implementation of the restoration measures. It is critical that during this phase an economic appraisal of the project is undertaken to examine the relationship of the project with the overall development objective of the river basin management plan. This should include a cost-benefit analysis of the proposed project options. The benefits accruing from the project option should be estimated and where possible compared to alternative projects or proposals. The main beneficiaries of the project are assessed, particularly in terms of the WFD objectives described earlier. When considering formulation of the action plans it is critical that the goals set are achievable, the costs of the action and who pays are identified, and finally the actions represent value for money or have considerable non-tangible benefits that can be recognised by society. This can only be done if clear agreement over the issues is made between the various user groups. Application of the aquatic resource management planning methodology described here will resolve conflict between user-groups enabling a compromise to be drawn up that focuses upon all of the relevant scenarios and what can be justified and implemented.

3.2.5 Risk and uncertainty

Once restoration measures have been identified, they need to be assessed for risk and uncertainty to confirm they are environmentally, socially and economically acceptable. This phase may also prove to be another source of conflict because there is a need to establish who is willing to pay for the restoration project, and what resources cost. Contingent valuation methods carried out as part of the consultation process will establish how much users are willing to pay for appropriate changes or how much they are willing to accept in terms of increased cost to still participate in the activity. Economic assessments of this type will help avoid problems during implementation because they take on the opinions of the user groups (Brouwer *et al*. 2015).

3.2.6 Prioritise restoration projects

The final step in the planning process is prioritisation of the most appropriate restoration measures based on environmental, social, technical, financial and institutional criteria, especially in the light of budgetary constraints which hitherto will not have been considered. Although there has been recent huge investment in restoration projects, prioritisation is still lacking (Johnson *et al*. 2003), and it is advised prioritisation and decision support should always be included as a foundation in restoration planning (Reichert *et al*. 2015). Good planning of restoration will enable prioritisation of projects, habitats, river reaches or watersheds to determine their sequencing for funding and implementation; the restoration goal will also help determine the criteria to include in the prioritisation approach (Roni *et al*. 2013 *in* Roni & Beechie, 2013). Knowledge of catchment processes, sub-units and their interaction with the larger ecological network is vital when prioritising river restoration. For example, it is important to understand when to protect an existing high quality habitat or other critical ecosystem and when to prioritise an individual species and its habitat requirements over larger more general restoration activities (Speed *et al*. 2016). Scale and connectivity play a major role within the prioritisation of projects, small scale projects are often more feasible and therefore should be prioritised to work towards an overarching goal at a larger scale. Whereas longitudinal and lateral connectivity should be increased using the 'stepping stones' approach which aims to restore a number of small river sections to provide habitats for migratory species (Klauer *et al*. 2015).

Economic valuation of restoration projects should always be incorporated into prioritization during restoration planning, and guidelines for practitioners should be made available (Brouwer *et al*. 2009). During this stage, it is essential the economic costs of restoration actions need to be balanced against benefits in terms of renewed or enhanced ecosystem services delivery (Brouwer *et al*. 2009).

3.2.7 Design monitoring programmes

Monitoring and evaluation plays a key role within the project framework because it enables identification of river restoration project success. Pre-monitoring helps identify restoration goals, while restoration goals help defining specific monitoring objectives to guide the development of a monitoring and evaluation programme. Monitoring elements should be chosen with a focus on those that respond to the restoration action and address the question outlined in the restoration goals.

Articulating a monitoring programme is essential to make the data meaningful for evaluation, i.e. determining the spatial and temporal scale for monitoring and identification of treatment, control and reference sites. Monitoring not only helps to define benchmarks and endpoints at the start of a project but also determines when the endpoint of a project has been reached. Long-term monitoring data are needed to improve understanding of trajectories of change induced by restoration measures (Friberg *et al*. 2016a). However, it can be difficult deciding when the restoration process is 'complete' and therefore, it is essential that an impact assessment monitoring design is employed to provide evidence, in statistical terms, that an endpoint has been reached (Buijse *et al*. 2005).

A variety of impact assessment techniques are available to detect environmental change for restoration project whose data collection methods differ spatially and temporally. A replicated BACI (before/after and control/impact) design is the most powerful design because it consists of sampling before and after at the impacted (restored) site and also at a control site to account for environmental variability and temporal trends and therefore increases the ability to differentiate treatment effects from natural variability (Roni & Beechie, 2013). A resource calculation can be applied to determine how many years pre and post monitoring is are required to isolate the environmental impact from natural variability (Sedwick, 2006).

The evaluation phase for a restoration project is only possible where a series of measurable indicators or endpoints have been established and monitored for the project. The evaluation phase will use indicators to gauge how far the restoration project has developed in relation to the initial objectives and defined endpoints. Assuming all goes well and the project is implemented, the evaluation phase should provide a steady feedback of information and results, which will be useful in other restoration project situations. An adaptive management approach, supported by the evaluation phase, provides a feedback loop within the planning framework (Figure 2) and this flexibility ensures changes are made when new information is generated to reduce critical data gaps and uncertainties, whether this is modifications to project goals, restoration techniques, or monitoring design and time frames. This is especially important for larger more complex restoration projects; by planning and monitoring smaller sub-projects, information can be gathered to make modifications that will contribute to overall improvements towards a larger project. Progress reports should be formally produced, assessed and made publically available, focussing on the key indicators of the project so lessons may be learned and problems avoided in future restoration programmes.

3.3 Project Implementation

The culmination of project identification and formulation phases should result in a project that can be successfully implemented. The implementation phase is characterised by the detailing of work plans and financial arrangements that will have been refined several times in earlier steps and be translated into activity schedules. Disbursement of project funds into budgetary headings will be implemented and all the monitoring and control mechanisms should be in place.

Unfortunately, all projects still face problems no matter how well a project has passed through the early stages of assessment. These problems may occur as a result of difficulties inherent in the development process or from more specific causes. Those who implement the project may find that although the development objectives of the project are constant, implementation will often deviate from the route originally envisaged. The problems range due to time constraints and cost underestimation difficulties to severely distorting effects involving difficulties in land use change, project inflexibility and further degradation of resources (e.g. fish stocks, water quality). It should also be recognised that inputs to this phase of the planning will vary depending on the scale of the restoration project. Small individual projects such as fencing a section river to reduce bank poaching will require less time in the planning process than a river basin plan, the latter of which requires more complex planning as described, and therefore more time.

3.4 Project monitoring & evaluation

Once a project is implemented, post-monitoring is essential to evaluate river health and assess benefits, and should be incorporated into the monitoring design developed in the project formulation phase. There is a wealth of literature to guide project evaluation, such as the PRAGMO (Practical River Restoration Appraisal Guidance for Monitoring Options) guidance to assist practitioners in the process of setting monitoring protocols (Hammond *et al*. 2011) and Stream and Watershed Restoration—A Guide to Restoring Riverine Processes and Habitats (Roni & Beechie, 2013). The evaluation phase is only possible where a number of measurable indicators (e.g. in Europe the WFD compliant Biological Quality Elements such as fish, invertebrates, water quality) have been established to gauge how far the restoration project developed in relation to the initial objectives and defined end points (Friberg *et al*. 2016a). In addition, cost benefit analysis can provide evidence that restoration was worthwhile in terms of environmental improvement and socio-economic investment of public and private money (Ayres *et al*. 2014). Project evaluation should guide future restoration management actions and update project goals. Furthermore, outputs, whether successful or not should be made publically available.

4. DISCUSSION

There has been a rapid increase in restoration activities to improve ecological status of rivers and standing water bodies, but little is still known about the effectiveness of such restoration efforts (Bernhardt *et al*. 2005; Roni *et al*. 2008; Roni & Beechie, 2013). Whilst the underlying reasons for the paucity of project outcomes is complex, poor project planning appears to be a key reason for failure to report project success (or failure), and is often attributable to limited guidance for river restoration planning and subsequent methods of evaluation of project success. Evaluating river restoration projects and exchanging sound river restoration practices is a much needed step in restoration ecology to highlight outcomes of what is huge investment of public money. The findings from the literature and existing case studies highlighted the need for a new integrated project planning framework that endeavours to overcome challenges when determining river restoration success or failure. The framework encapsulates management techniques that problem solve and produce a strategy for the execution of appropriate restoration projects to meet specific environmental and social objectives, and to evaluate success. It follows several logical steps, such as project identification, project formulation, project implementation and post-project appraisal, to ensure the approach is transparent, repeatable, and achieves its objectives. The review of the literature and EU case studies concluded that the concepts of reference conditioning, benchmarking and success evaluation endpoints need to be more highly developed and promulgated in a way that is useful to river managers, project partnerships and stakeholder groups. The framework sets out to produce target-driven objectives by categorising river condition, identifying factors degrading aquatic habitats, selecting appropriate restoration actions, and monitoring and evaluating restoration actions at appropriate scales.

In this paper the importance of good project planning to work towards effective project evaluation and hopefully project success has been highlighted, however, it should not be assumed that a perfect project plan alone will lead to project success. Indeed, this is rarely the case and there are additional unforeseen factors and externalities that are not necessarily part of the planning process that may also determine a project outcome. Some of the main factors that influence project success or failure (modified from Wielen & Makaske 2007), include, but are not exclusive to:

Project success:

- Having the drive and determination to ensure projects come to fruition and are implemented in a timely manner;
- Integrating less tangible nature based restoration measures with stronger societal functions and activities (e.g. flood protection and hydropower);
- Adopting large-scale integrated approach assembling and integrating aims of multiple projects to maximise the benefits accrued at a catchment scale;
- Cooperation of public and private sectors, including contributions to physical works (volunteering) and finances;
- Wide stakeholder support through timely communication and participation and feedback;
- Multidisciplinary project team covering all engineering, hydrogeomorphological and ecological, social and economic dimensions of the project;
- Good financial agreements, including contingency plans for adaptive management;
- Joined up thinking, working at a catchment scale where upstream and downstream bottlenecks are addressed in synergy with proposed project.

Project failure:

- Too few multiple aims reducing wide support and possible financing;
- Lack of correspondence between relevant policies and regulations;
- Lack of involvement of and engagement with key stakeholders and societal actors;
- Misconduct and lack of rigour in project coordination and discontinuity of phases of the project implementation;
- Too little financial support and contingency for unforeseen and unexpected outcomes;
- Large organisational and financial complexity causing delays and adjustment of project aims and endpoints;
- No long term plans for river management after completing;
- No long-term monitoring to assess whether long-term objectives sustainable;
- Political override caused by changes in government policies, changing financing systems, responses to public outcries (e.g. dredging as a response to flooding) and lack of understanding of benefits of restoration actions.

Many of the unforeseen factors listed above that could lead to project failure tend to be government or organisational issues that are socially complex because of multiple user groups and policies that often have conflicting goals. River managers are restricted by the time scale in which they are awarded funding to deliver projects; financing rarely tends to be long term and rarely allows for unforeseen outcomes and adjustments in project design. This limits the development of restoration planning, monitoring and evaluation, and reduces the likelihood of project success. To overcome this, it is recommended that national and regional policy drivers and financial instruments must include appropriate monitoring programmes, methods for data management and dissemination, protocols for data analysis, and the publication of results in formats that are useable by river managers. Guidance for this has been developed over the past few years, such as REFORM (http://wiki.reformrivers.eu) and RESTORE (https://restorerivers.eu) WIKI tools that support river managers by providing interactive guidance for river restoration planning and a platform to share and disseminate outcomes from restoration projects. Furthermore, the partnership approach encourages the sharing of such data, which, in addition to the citizen science methodologies (Huddart *et al*. 2016) will develop new opportunities for data collection to overcome the funding and time restrictions and can be incorporated into the monitoring design at a fractional cost.

Although the development of catchment scale management is increasing, it is often constrained by inadequate funding, which will therefore influence restoration priorities leading to single, small scale actions being the most frequently employed, with little or no association to catchment plans at a larger scale. Small scale restoration measures are often cheap, easy to apply and quick to accomplish, but cam often have little impact. In some cases they almost become aesthetic in nature (‘gardening’) and have no obvious environmental benefit. Also some small scale projects are in such isolation that the bottlenecks to degradation are not address so project success is unlikely in the foreseeable future. As a consequence, it becomes important to understand how to apply small scale restoration to benefit the wider environment and using process-based ecological restoration techniques as an alternative could restore desirable habitats (Kondolf *et al*. 2006). Reviewing the current status of the water body and identifying water body goals and specific objectives during the project identification phase will ensure small-scale restoration measures are incorporated into catchment planning, such an approach is being adopted as part of the CaBA (catchment based approach) in the UK (http://www.catchmentbasedapproach.org/).

Furthermore, incorporating adaptive management into river restoration project design and management could simultaneously overcome unforeseen factors and therefore reduce uncertainty in project delivery and success. Adaptive management is a treatment for uncertainty, its application alongside the project planning framework proposed in this paper provides an overall approach to overcome scale-specific problems for complex systems (Williams & Brown, 2016). Additionally, adaptive management and frequent assessment during the life of a project will allow restoration results to be compared with expected outcomes to adjust restoration actions from original plans and encourage reactive decision making to overcome unforeseen problems. Adaptive management is ideal for decision making that is usually based largely on subjective judgements because it allows decisions to be supported by scientific evidence (Boon & Raven, 2012; Williams & Brown, 2016), especially for small projects, or a sequence of projects working towards a larger goal or complex projects on large rivers or catchments. Examples of this are the Columbia, Platte, and Missouri Rivers (Quigley & Arbelbide, 1997; Wissmar & Bisson, 2003; Williams, 2006; Freeman, 2010),

The interpretation of river restoration success can vary between stakeholders and sectors, particularly as they will have different targets and indicators of success (Howe & Milner-Gulland, 2012; Jones, 2012), and this can be somewhat problematic. For example, river restoration project objectives can vary across economic, social and ecological dimensions and in most instances all three will play an important role in defining outcomes. Numerous projects consider economic and social aspects, such as those protecting infrastructure and re-building parks where no direct ecological improvement has been targeted. For example, Sutcliffe Park, River Quaggy – Chinbrook Meadows and River Pool Linear Park Enhancement projects in the UK are restoration projects that aim to protect against flooding whilst generally being aesthetically pleasing to the public; but they do not necessarily consider ecological improvements such as river processes or biota (RESTORE River WIKI https://www.restorerivers.eu/). Projects like these mitigate potential pressures but it is not necessarily imperative that they restore ecological restoration; this should be clearly identified in project aims, objectives and targets for evaluation.

In using the framework it is important to recognise that each restoration scheme proposal should be treated individually as no situation is alike. It is therefore impossible to provide one set of threshold criteria to measure restoration success for all projects; this must be the responsibility of an expert panel, which will assess the information provided and evaluate the overall risk of a scheme not having environmental and social benefits that are commensurate with costs. However, if the framework is applied correctly the approach should be a transparent and repeatable system.

The proposed river restoration project planning framework is adaptable and can therefore be applied to any small or large project development locally, regionally or internationally. It provides guidance in the collection of key information for decision making such as providing knowledge of the technical policy and background, to conflicts of multiple users of resources and develops a plan for comparison of status with objectives at a catchment scale. This therefore ensures that river restoration projects are prioritized within the river basin and will ensure small scale projects work towards overarching catchment goals.

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