Monitoring of Ecological Response to River Restoration

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Nature-based solutions are widely advocated for freshwater ecosystem conservation and restoration. As increasing amounts of river restoration are undertaken, the need to understand the ecological response to different measures and where measures are best applied becomes more pressing.

Keywords: river restoration ; monitoring ; appraisal ; best practice

1. Introduction

Despite their critical role in maintaining biodiversity and the essential socioeconomic services they provide, the importance of freshwaters and the need to treat them responsibly is often overlooked. Indeed, according to the Living Planet Index, there was an 84% decline in freshwater vertebrate populations 1970–2016, and almost one in three freshwater species is threatened with extinction [1]. Increasing attention is now being paid to the restoration of ecosystems to help limit and mitigate the effects of climate change, to ensure the sustainable provision of essential ecosystem services, and to stem the loss of habitats and species. The United Nations has proclaimed 2021–2030 to be the Decade on Ecosystem Restoration [2], with freshwater ecosystem conservation and restoration a major theme [2].

In 2013, the River Restoration and Biodiversity Programme was established under the auspices of the International Union for the Conservation of Nature National Committee United Kingdom (IUCN NCUK [3]). The aim of the Programme is to provide robust evidence for the biodiversity benefits of restoring rivers. The Programme defines river restoration as “the re-establishment of natural physical processes (e.g., variation of flow and sediment movement), features (e.g., sediment sizes and river shape) and physical habitats of a river system (including submerged, bank and floodplain areas)”. This approach uses nature-based solutions to restore natural processes to create a characteristic, self-sustaining, dynamic physical habitat that facilitates ecological recovery [4][5].

Understanding the response of biota to river restoration intervention is important when determining whether ecological objectives have been met, whether adaptive management is necessary, and to learn lessons for future projects [6][7]. It requires the collection of meaningful data to determine whether a project has been successful [8][9]. However, most projects have not implemented effective monitoring to assess the outcome of restoration [7][10], and there has been a reliance on subjective perceptions of success [11]. If we are to understand and implement restoration measures effectively, their success must be rigorously evaluated [5][12].

The ongoing lack of research and monitoring following the recovery of degraded ecosystems means that theories about the trajectories of ecosystem change following restoration remain unclear [13][14]. Without confidence in the theoretical framework, developing generalised strategies for the evaluation of change following a restoration intervention is difficult. In short, we remain in a data gathering phase.

To address these gaps, in October 2018 as part of the IUCN (NCUK) River Restoration and Biodiversity Programme, a workshop of invited river restoration appraisal academics and practitioners was held. Its aim was to explore best practices and incorporate academic knowledge to develop a scientifically robust monitoring protocol for appraising the biodiversity benefits of restoration [15].

2. History of Restoration Appraisal

In the 1990s, river restoration became established as an important method for the rehabilitation of river ecosystems [16][17][18][19]. Concurrent with this increase in restoration activity was the call for comprehensive monitoring, including flag-ship demonstration projects [20] and well-structured monitoring and appraisal [21] that take an ecosystem approach [19]. Despite

the recognition of the importance of monitoring change, restoration measures were often implemented on the assumption that the restoration of habitats would be followed by improvements in biodiversity. This approach is characterised by the phrase “if you build it, they will come”, otherwise known as the “Field of Dreams hypothesis” [22]. The lack of appraisal meant that the success of restoration measures was poorly understood. A 2007 review found 89% of project contacts reported success but only 11% of the projects were considered successful due to a measurable ecological response [23]. Similarly, in 2016, the UK National River Restoration Inventory compiled by the River Restoration Centre contained over 2800 completed projects with only 21% reporting any monitoring. Of the 179 projects added to this inventory in 2017, only 5% specifically reported any monitoring outcomes [24]. A review of restoration work in California, USA, found that very few projects had been subjected to post-project evaluation resulting in a lost opportunity to learn and improve future design [25]. This view was supported by others who also concluded that poorly planned appraisals can be misleading [26].

Despite an increase in the number of published restoration appraisals [27], there is still a noted lack of monitoring and appraisal [12][28]. There is also a lack of consideration of how to monitor project success effectively and the inherent difficulties in doing this [29]. These appraisals are illustrated by poorly planned inappropriate monitoring strategies [7][30] and recommendations to undertake monitoring with more rigor to increase the likelihood of detecting actual changes in biodiversity [5][31], as well as linking hydromorphological changes to ecological responses [32][33].

3. Towards More Effective Appraisal of River Restoration

Discussions at the 2018 IUCN (NCUK) workshop concentrated on developing recommendations to complement existing guidance and established best practices. Specifically, all restoration activity should be undertaken within an integrated project framework. This framework should ensure there are sufficient baseline data to characterise the current status, identify causes of degradation, plan effective solutions, and set restoration targets [12][34][35].

Once restoration targets have been established they should be turned into clear SMART (Specific, Measurable, Achievable, Realistic, and Time-bound (e.g., [36]) objectives that are linked to project goals and predicted outcomes [17][21]. A lack of defined objectives and success criteria or end points against which to measure success has also been identified as a problem in river restoration appraisal [12][29].

The development of target outcomes or ‘expectations’, therefore, requires either historical information about the system that is to be restored, information from ecologically similar but undisturbed ‘reference’ sites, or expert opinion based on empirical and/or theoretical models [26]. Quantified expectations allow the testing of scientific hypotheses about how systems respond to restoration [37][38]. The expectations must be set in the context of catchment condition and processes and should consider restoring both structural complexity and functional integrity [39] (**Figure 1**). Setting expectations or targets in a catchment context allows the interactions with other anthropogenic stressors to be considered [32][40][41]. Expectations should also consider projected future changes within the catchments of restored rivers including climate change and likely land use changes such as urban development.

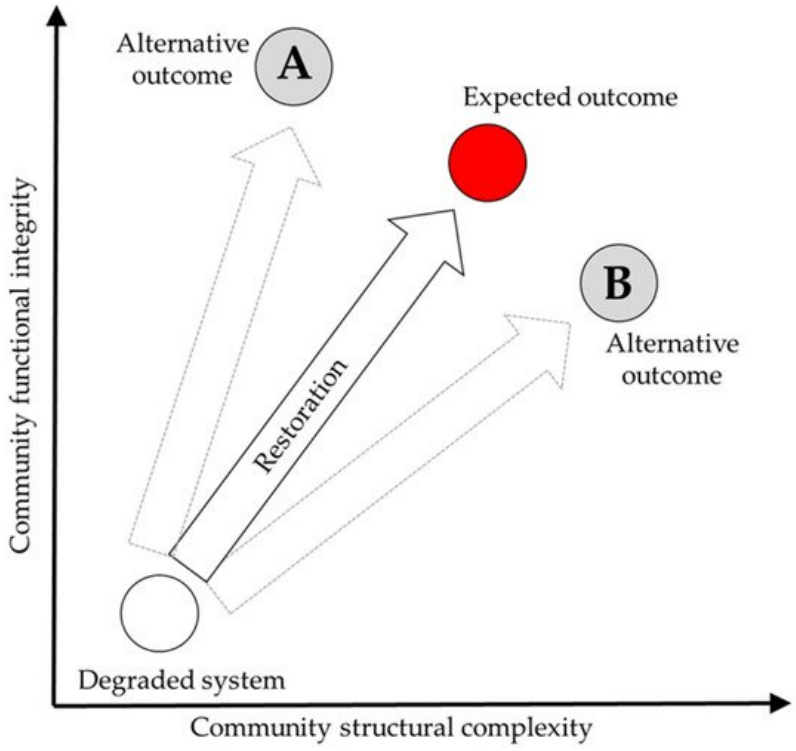

Figure 1. A general model of ecological restoration, where the objective is to increase structural and/or functional complexity.

Exactly what is monitored to support the appraisal of restoration outcomes will depend on the impetus for a scheme and the scale of the restoration [5]. However, it should follow an integrated ecosystem approach [18] that includes geomorphological, habitat, and biota assessments [4][5][17]. Where practicable, assessments points should be colocated [29] to help understand biotic responses to habitat change.

Legitimacy of restoration appraisal requires the scientific review and public dissemination of findings [5], yet appraisals are often poorly documented [34]. There are two main dissemination routes: publications in peer-journals and less formal forums. Journal publication ensures scientific robustness and knowledge sharing. Less formal routes such as the EU-RiverWiki [42], (an online tool used for sharing information on river restoration projects) allow wider dissemination and the sharing of less detailed studies, which can contribute to the weight of evidence of restoration success. To ensure the field of river restoration continues to advance, results should be shared regardless of whether they are positive, negative, or ambiguous [11][13][21][29][34][43]. The importance of engaging project stakeholders at this stage should not be overlooked as this can be critical to promoting buy-in for future projects.

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