The problem of river restoration persistence

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Key Points

- Lack of maintenance is a widespread problem with river restoration projects
- The design of management arrangements is just as important as design of the works themselves
- How projects are managed should be informed by the recovery trajectory of degraded assets
- Some interventions become self-sustaining while others require ongoing maintenance

Abstract

Environmental infrastructure and practices designed to repair and protect aquatic systems are now mainstream. Yet, many of these infrastructure and practices are failing because of poor maintenance. How maintenance is managed is just as important for success as how the project is designed and implemented. Successful maintenance relies on understanding the recovery trajectories of aquatic systems. Some will recover over decades, some require maintenance in perpetuity.

Keywords

River restoration, maintenance, management, environment, recovery, trajectory

Introduction

Over the last thirty years the focus of river and stream management has shifted from utilitarian benefits such as flood prevention (Tompkins & Kondolf 2007), towards restoring natural values to waterways, and protecting ecosystem services (Bernhardt et al 2007). This period has been an experiment in designing and establishing solutions to degradation. As the restoration industry matures the experiment is close to an end. Building restoration structures and establishing practices is now a routine component of river management. Societies in economically developed river basins have made excellent progress at implementing river restoration projects for assisting the recovery of degraded high-valued assets (Smith 2013) such as fish communities, or wetlands. Restoration is achieved first, by establishing infrastructure, such as riparian fencing and fishways, second, by reducing the prevalence of damaging practices (such as desnagging and channelization), and thirdly, by introducing new practices like delivering environmental flows and re-snagging. A major challenge now is to maintain these works and practices into the future, as well as to avoid the re-emergence of damaging practices. As many interventions take a long time to produce ecological outcomes, the level of deterioration of intervention infrastructure and practices (i.e. maintenance) is an important interim evaluation point for the success of project delivery (Rutherfurd et al 2004). This paper argues that how projects are managed and maintained in the long-term is as important to their success as how they are designed. Lack of maintenance is a key cause of restoration failure. Suding (2011) suggests of the restoration movement that, “Given the rapid expansion of a young discipline, growing pains are not surprising” (p.466). To improve the success of future restoration projects we must understand why maintenance is neglected and how lack of maintenance affects different types of interventions.

Not surprisingly, the emphasis in the literature has been on encouraging communities to adopt restoration practices, and on establishing legislation to restore public waterways. There have been many calls to better monitor and evaluate the performance of works and projects (Palmer et al 2007; Brooks & Lake 2007), and develop guidelines for restoration (Beechie et al 2010). Studies now demonstrate the challenges with the design (Roscoe & Hinch 2010), construction (Heede 1977), monitoring (Bernhardt et al 2007; Kondolf et al 2007), and initial implementation of restoration intervention. The problem of maintenance is less widely recognized, although several authors have identified that river restoration interventions often fail because of lack of maintenance (Kulmatiski 2006; Shields et al 2006). More widely the focus of restoration has been on ecological goals rather than the social, political, and economic mechanisms through which on-ground projects are implemented and maintained. Thus, as the aquatic restoration industry progresses, a key issue now is how to maintain interventions over the long-term in order for infrastructure and practices to persist.

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This paper outlines the problem of river restoration persistence which can be defined as the failure to maintain restoration infrastructure and practices over the length of time, and with the regularity, required to achieve the desired environmental outcomes. Maintaining restoration practices (such as environmental flows) is just as important as maintaining infrastructure. Thus, maintenance here refers to the upkeep and replacement of physical infrastructure, the continuation of site management practices, as well as the effective ongoing communication of project goals to the involved community groups and individuals. This paper asks the question: even if restoration activities are implemented perfectly, how can they be maintained in the long-term? In this paper we make two key contributions:

- Present a classification of types of interventions, and the maintenance that they require.
- Second, we demonstrate that the problem of 'restoration persistence' is very much a management problem as opposed to a problem of design, construction, and ecological monitoring. Biophysical trajectories of environmental recovery should inform the selection of management arrangements and the rigour with which those arrangements are maintained.

A Persistence Framework

A basic foundation of environmental restoration is that the improvement achieved through intervention should persist. Interventions fail when projects are not maintained over an appropriate timeframe for degraded environmental assets to recover. The Persistence Framework can assist managers by answering questions such as: will an intervention become self-sustaining or need ongoing high-level maintenance? How much funding, staff, and, and hours will an intervention require to produce environmental outcomes? What management arrangements will best achieve the necessary maintenance? To answer these questions the Persistence Framework classifies restoration infrastructure and practices into two categories: self-sustaining and ongoing (Table 1), according to the recovery trajectory of a degraded asset in response to the intervention (Simenstad et al 2006). A recovery trajectory is a prediction of length of time required for an intervention to achieve environmental outcomes, and whether degradation will reoccur if the intervention is neglected or discontinued. The underlying biophysical processes of recovery determine the time required for a degraded asset to recover (Beechie et al 2010) and how long restoration infrastructure and practices must be maintained to produce ecological outcomes.

Restoration trajectories can be determined by whether an intervention addresses the underlying cause of disruption to biophysical processes versus addressing symptoms of degradation, and capacity to develop resilience to disturbance. Restoration projects that address the causes of degradation restore natural processes while projects that address symptoms simulate natural processes, often with engineered solutions. Consider wetland restoration; *cause-focused* intervention might involve reinstating natural flow regimes. In contrast *symptom-focused* intervention might involve delivering environmental flows that simulate natural flows patterns.This is an important distinction for two reasons. Firstly, engineered solutions usually require ongoing maintenance to be successful while solutions that reinstate natural processes can become self-sustaining. Environmental flows must be delivered to a degraded wetland for as long as the river system is regulated. Secondly, interventions that reinstate processes such as overbank flooding are usually more successful in the long-term than interventions that imitate the outcomes of natural processes such as reconnecting river channels with floodplains (Beechie et al 2010). Despite the obvious benefits of process-based interventions, many restoration projects are constrained by social, political, and economic factors that favour engineered solutions (Darby & Thorne 1995; Davidson 1981). As a result many restoration projects must be maintained indefinitely.

Interventions that must be maintained in perpetuity also tend to have a low capacity to develop resilience to disturbances such as flooding and drought. Intervention resilience is the capacity of an intervention to continue serving a restoration function after disturbance. Most interventions will require additional maintenance after disturbance however some may develop resilience as projects mature. For example gully control structures sustain less damage from flooding once vegetation has established and stabilized erosion (Weinhold 2007). We refer to the reduced impact of disturbance on an intervention as 'intervention resilience'. By contrast fishways are likely to need increased maintenance after flooding regardless of the length of time the structure has been in operation. An in depth examination of resilience goes beyond the scope of this paper however, it should be noted that many restoration projects can be vulnerable to flood damage, and the need for additional maintenance after flooding should be factored into management planning. In the remainder of this section common restoration interventions are classified into categories based on the length of time required for restoration to produce ecological outcomes, and whether an intervention addresses causes or symptoms of degradation.

Table 1. Examples of restoration classification

	Practices	Infrastructure
Self-sustaining	Revegetation, sediment extraction, re-snagging	Gully control structures, log-jams
Ongoing	Constructed wetlands, environmental flows, excluding cattle from fenced frontage, weed management	Riparian fencing, fishways, flow regulators

Self-sustaining interventions

Self-sustaining interventions include practices such as revegetation and sediment extraction, and infrastructure such as gully control structures and log-jams. The time required for self-sustaining interventions to achieve a state where no further maintenance, or minimal maintenance is required, varies along a continuum of years, decades, and centuries. To determine this timeframe the path a degraded asset is expected to take towards an improved ecological condition must first be known (Simenstad et al 2006). The trajectory depends on the specific response time of the biophysical processes involved in restoration to the intervention.

Gully control structures combined with revegetation can become self-sustaining within a decade (Hansen & Law 2008; Weinhold 2007). Revegetation addresses the cause of gullying by reducing the impact of surface flows and stabilizing infrastructure. In contrast sediment extraction for the management of sand slugs can require decades to achieve outcomes. For example, Rutherfurd (2001) outlines a management strategy for sediment extraction to rehabilitate the Glenelg River. The recovery trajectory can be determined from the sediment transport rate, the composition of the riverbed, and the amount of stored sediment in the channel and floodplain (Rutherfurd 2001; Bartley & Rutherfurd 2005; Erskine 1994). Depending on the regularity of extraction, environmental outcomes may be achieved in 40 to 100 years (Rutherfurd 2001). In contrast re-snagging for restoring in-stream habitats may take over a century to become self-sustaining. Figure 1 demonstrates how a recovery trajectory can be plotted for restoring instream wood and how a maintenance trajectory might be determined based on predictions of recovery.

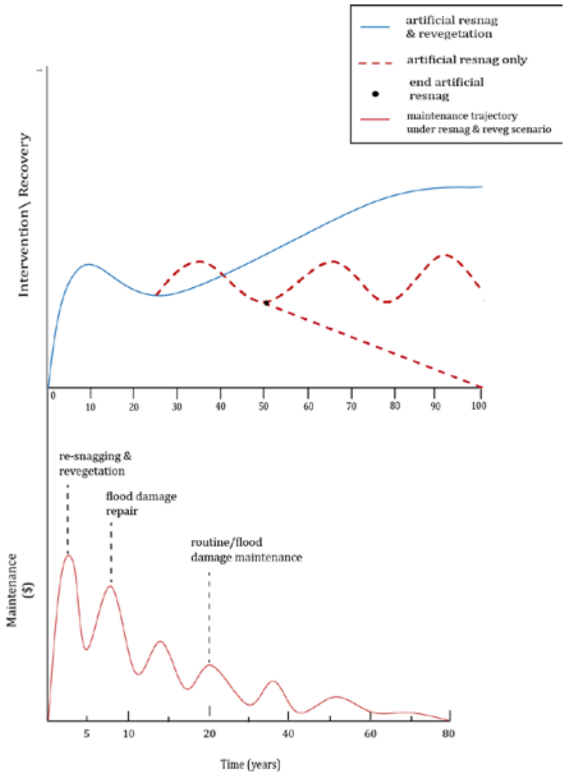

Figure 1: Recovery trajectory and maintenance trajectory

Wood removal and vegetation clearing are two causes of in-stream degradation. In Figure 1 artificially reintroducing wood into rivers at time '0' addresses an immediate symptom of land use changes in catchments, while revegetating the riparian zone addresses the more permanent cause of low wood-loads in rivers. Artificially introduced wood must be maintained in river channels for between 40 years (Wheaton et al 2011) to 100 years (Erskine & Webb 2003) before riparian vegetation has matured into a natural source of woody debris (Lester & Boulton 2008). This understanding of recovery processes translates into a maintenance trajectory that indicates when, how much, and for how long maintenance is required to reinstate natural wood loads in desnagged rivers. Only artificially resnagging will need to be maintained indefinitely to be effective while both resnagging and revegetation is likely to become more self-sustaining and require declining amounts of monitoring and funding over time. Under this scenario the need for maintenance decreases as riverbank vegetation matures. This is an important distinction from interventions that resnagg without revegetation because the latter will require more robust management arrangements.

In practice there are few interventions that will not require some form of future management, however minimal. Nonetheless the idea that some interventions can achieve relative self-sufficiency compared to other interventions which must be maintained to a high level indefinitely, has important implications for how projects are managed and funded in the long-term. Practitioners of river management can use this framework to make decisions about the longevity of funding and regularity of monitoring resnagging projects, as well as identifying potential challenges at the outset of projects.

Ongoing interventions

Ongoing interventions are infrastructure and practices that must be maintained in perpetuity to achieve environmental outcomes, such as fishways, flow regulators, and practices like delivering environmental flows. If the intervention ceases, or is disturbed, the trajectory of recovery can reverse and degradation will reoccur. The amount of effort and funding required to maintain ongoing interventions in the long-term varies. Interventions that require a larger amount of maintenance effort and funding pose the greatest risk to restoration as they require more robust management arrangements, such as reliable funding streams and the clear delegation of responsibility for maintenance.

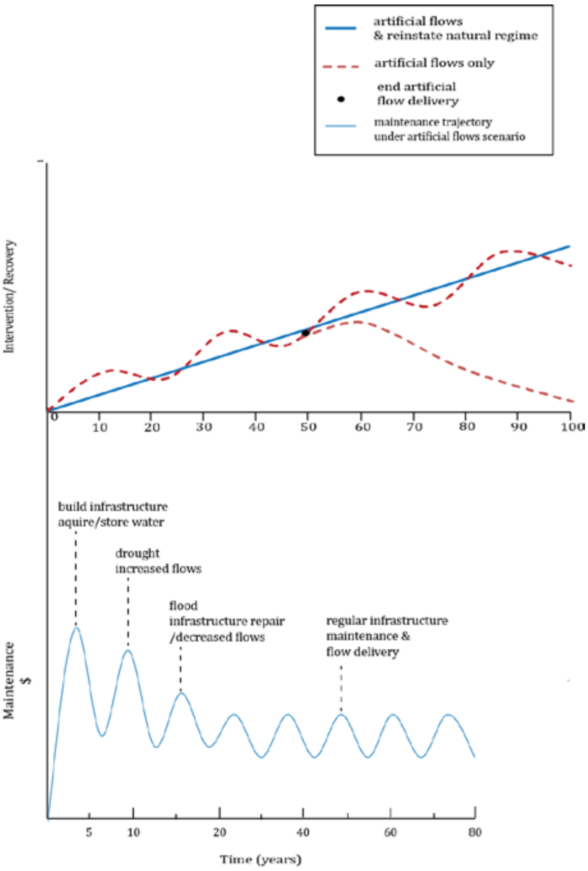

Figure 2: Wetland recovery trajectory & maintenance trajectory

As suggested above there are often social, political, and economic reasons why restoration programs address symptoms rather than causes of degradation in river basins. Ongoing interventions tend to mitigate the impacts or symptoms of continuing practices. For example there are numerous options for wetland restoration including delivering environmental flows artificially or reinstating natural flow regimes. Environmental flows are used to improve the environmental condition of natural wetlands because governments are often reluctant to reduce irrigation entitlements.

Figure 2 demonstrates that delivering environmental flows will need to be maintained in perpetuity compared to reinstating natural flow regimes and floodplain-river channel connectivity. The top graph shows that while both restoration options may result in wetland recovery, wetland condition is likely to decline if environmental flows are ceased in the absence of reinstating natural flow regimes. This suggests environmental flows should be managed through strong management arrangements that will ensure flows are delivered for as long as river regulation continues in river basins. The bottom graph shows that a high level of maintenance will be required to deliver environmental flows regularly even without the additional complication of drought or flood events.

Infrastructure that requires ongoing maintenance includes flow regulators, riparian fencing, and fishways. Flow regulators are designed to allow the targeted flooding of specific locations on wetlands without damaging surrounding private property (Jones et al 2002). Fishways on dams overcome barriers to fish movement. Riparian fencing is established to mitigate degradation caused by cattle grazing on floodplains and accessing rivers (Miller et al 2011). In general, restoration infrastructure like fences, fishways and flow regulators, require less intensive maintenance than practices that occur over wider spaces like the ecological restoration of a wetland or herding cattle to alternative watering sites. The amount of effort required to maintain ongoing interventions indefinitely should be a central consideration for management decision making. The persistent nature of these interventions indicates that more persistent management arrangements are required. In the next section we outline the main types of management arrangements that are used to implement restoration and draw on the Persistence Framework to consider which arrangements are most suitable for self-sustaining and ongoing interventions.

Approaches to Maintenance

A range of maintenance arrangements are available, including legal regulation, voluntary instruments, and market based instruments. There is not space here to address the broad issue of which if these arrangements is most suitable for different types of project. However, we can make the following observations:

ongoing interventions tend to require more robust management arrangements such as legal instruments, and that MBIs and voluntary instruments are more likely to succeed for self-sustaining compared to ongoing interventions. This is not prescriptive however legal instruments often offer greater security for intervention persistence. We also observe that poorly suited and poorly executed arrangements can be a cause of maintenance failure.

Traditional legal regulation

Traditional regulatory instruments include: legislation, parliamentary Acts, and licensing (Gunningham & Young 1997). Implemented well, legal instruments are ideal for ongoing interventions as they are permanent and attract large funding streams. To be effective regulations require the following: adequate funding, transparency and communication between tiers of governance (Watson & Emery 2004), perceived legitimacy and non-compliance penalties (Shimshack & Ward 2005). An example of well implemented regulation is the establishment of environmental flows (an ongoing intervention) in Australia under the Commonwealth Water Act 2007. Governing bodies were created and funds allocated at the state and Federal level to acquire and manage environmental water. In contrast maintenance failure can occurs when regulations are not enforced and monitored. This is a widespread problem for projects in public waterways and on public lands such as fishways (O'Brien et al 2010) and gully control works (Hansen & Law 2008) managed under Statutory Obligations.

Governments also use legal instruments to regulate restoration implemented by the business sector (Gunningham & Young 1997). To be effective government agencies must oversee and enforce compliance with license conditions (Hartig & Drechsler 2008). Mitigation wetlands are an example of ineffective legal regulation which has experienced widespread maintenance failure (Hallwood 2007) due to weak or ambiguous contracts, insufficient overseeing (OTA 1984), non-compliance with permit conditions (Ambrose 2000), and inadequate permit conditions (Reiss et al 2009). These examples highlight the importance of adequate monitoring, enforcement, and capacity to oversee all parties engaged in legal arrangements. Well implemented legal instruments are powerful tools for establishing and maintaining ongoing interventions.

Market-based & voluntary instruments

Market-based and voluntary instruments are increasingly popular with governments because they attach economic value to ecologically desirable outcomes (Coggan & Whitten 2005) such as conservation tenders, pollution credits (Greenhalgh & Selman 2012), carry less stigma than traditional regulation (Gunningham 2003), and put the cost of managing the environmental externalities of the agricultural sector back onto resource users (Quiggin 2000). To be successful there must be: a demand for both buyers and sellers, prices that reflect the cost of maintenance (Whitten et al 2007), the recovery of assets must be of equal value across all tradeable areas (Stavins 2003), and information sharing and trust between project parties (Race & Curtis 2013). A key challenge of using MBIs is market failure. In Australia water pricing was introduced to allow governments to purchase environmental water. In practice many landholders have opposed selling permanent entitlements (Qureshi et al 2010). To counter similar market failure American governments have established legal mandates to purchase environmental water when similar resistance from landholders has led to market failure (Tisdell 2010).

Voluntary instruments include certification, covenants, and agreements. To be successful voluntary instruments require: effective communication with landholders, non-compliance sanctions, benefits for landholders (Danne 2003), and threat of compulsory regulation in the case of non-compliance (Colby & Pearson d'Estrée 2000). Many voluntary arrangements become legally binding and require monitoring, such as voluntary agreements for riparian restoration in Victoria. The government funds the construction of fencing on river frontage and landholders are responsible for maintenance. In practice the cost of maintenance can be prohibitive and result in project failure. The New Zealand dairy industry has taken the next step and established an Accord with the dairy sector and government Ministries to achieve and monitor 90% exclusion of cattle from riparian areas, 100% exclusion from significant wetlands by May 2014, and 100% of stock river crossing points bridged by 2018 (DairyNZ 2013). While not legally binding the Accord will be monitored by the Ministry of Environment and is supported by dairy suppliers through a certification mechanism. The strength of the voluntary instrument is increased by certification that favours pro-environmental. Voluntary instruments can also be more appropriate for short-term projects as ongoing costs can be a barrier for landholders, such as the Landcare movement in Australia which experienced widespread burnout as the costs exceeded the benefits (Bathgate & Pannell 2002). Therefore voluntary instruments are most appropriate for projects with high direct benefits that reduce the need for monitoring (Kwak et al 2009). Instruments that offer few incentives for maintenance are more suitable for self-sustaining interventions such as revegetation which are less likely to require a high level of maintenance in perpetuity.

These examples demonstrate that maintenance is a dynamic problem related to the specific management arrangements that are used to implement river restoration infrastructure and practices. While maintenance failure also results when the right instruments are implemented poorly this is a problem of a different nature and may only become apparent after some time. Interventions, including infrastructure and practices, that require greater persistence should be maintained through more robust management arrangements.

Conclusions

The central principles of this paper are as follows:

- River restoration interventions fail when they are not maintained.
- How well projects are maintained depends on management.
- Decisions about management should be informed by the recovery trajectory of degraded assets.
- Maintaining practices is as important as maintaining infrastructure.
- Interventions which require more maintenance time and effort to achieve recovery need more reliable management instruments. Ongoing interventions pose the greatest challenge for river restoration because they may need ongoing funding and permanent arrangements for management.

- How projects are managed is as important as what they are designed to achieve.

Establishing new river restoration projects has been a central focus of the past two decades. The problem of maintenance has emerged as projects mature. The Persistence Framework offers a way of thinking about why maintenance is important for restoration and how to plan for success. Interventions should be implemented through instruments that ensure they will be maintained long enough to allow the degraded asset to follow the expected recovery trajectory through to an improved environmental condition. We have confidence in many of the infrastructural and practice-based solutions to degradation. The next big challenge is to establish the same faith in how our solutions are managed, and ensure interventions are maintained long enough to mitigate degradation. The key message of this paper is not that there is one ideal way to manage an intervention for success. Rather that some interventions require more maintenance than others and those which require persistent maintenance to be successful should be managed accordingly.

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