Title

When is Open-endedness Desirable in Restoration Projects?

Running title

Open-ended restoration

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ecological trajectories, forward-restoration, landscape-scale, non-equilibrial systems, novel ecosystems, dynamic ecosystem processes.

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Abstract

A low-intervention approach to restoration that also allows restoration outcomes to be framed as trajectories of ecosystem change can be described as ‘open-ended’ restoration. It is an approach that recognizes that long-term ecosystem behavior involves continual change at small and large spatial and temporal scales. There are a number of situations in which it is appropriate to adopt an open-ended approach to restoration including: in remote and large areas; where ecological limiting factors will be changed by future climates; where antecedent conditions cannot be replicated; where there are novel starting points for restoration; where restoration relies strongly on processes outside the restoration area; in inherently dynamic systems; where costs are high and where the public demands ‘wildness’. Where this approach is adopted managers need to explain the project and deal with public expectations and public risk. Monitoring biotic and abiotic components of the project are very important as an open-ended approach does not equate to ‘abandon and ignore it’.

Key Words

ecological trajectories, forward-restoration, landscape-scale, non-equilibrium systems, novel ecosystems, open-ended restoration.

Introduction

Higgs and Roush (2011) explore options for restoration in response to the indirect effects resulting from climate-driven changes in mountain ecosystems in remote locations. They set out 13 criteria for assessing the appropriateness of active attempts at ecological restoration in remote landscapes. The alternative management option (and the default without intervention) is to allow ecosystems to adapt on a new trajectory, even if this lies outside historical-reference conditions (Throop and Purdom 2006). Following Throop and Purdom (2006), Higgs and Roush (2011) consider that a non-intervention approach, is appropriate when 1) there is equal uncertainty about the trajectory of change with and without intervention, and 2) where the trajectory of change without intervention provides equal or greater benefits for the landscape.

Higgs and Roush's non-intervention or low-intervention approach has much in common with the open-ended approach to restoration described by Hughes et al. (2011). Many restoration projects are target-driven, with specific goals derived from reference systems. More open-ended approaches to restoration recognise that habitat change is continual, following unpredictable ecological trajectories, requiring restoration to be 'directed forwards' (Perrow and Davy 2002, p. xv). Hughes et al. (2011) describe the application of an open-ended approach to restoration in a lowland ex-arable fenland site in the UK. Restoration outcomes are expressed in terms of future trajectories of change (from dry species-poor ex-arable land to wetter, more species-rich and dynamic landscapes) rather than as specified restoration targets defined in terms of a historical fen reference system or its contemporary analogue.

The benefits of target-driven restoration are well proven and appropriate under many circumstances, particularly as a response to declining species or habitats, or particular anthropogenic impacts. However, this approach may not be appropriate in all circumstances. Here we identify some contexts in which a more open-ended approach to restoration may be justified.

What is Open-Ended Restoration?

An open-ended approach to restoration follows the approach outlined by Higgs and Roush (2011) in its emphasis on minimal intervention, and acceptance of future trajectories of ecological change. Projects might emphasise reducing or removing human influence and allowing habitats to form through both autogenic processes such as vegetation regeneration and succession and allogenic processes such as plant propagule dispersal and river flooding. Contemporary (and future) ecosystem processes dictate ecological outcomes. The new ecosystem's trajectory into the future will be influenced by its ecological inheritance and by species colonisation and extinction rates, and will thus form novel species assemblages. Management approaches may be low intensity, but should comply with the necessary minimum legal requirements (for example control of designated noxious weeds).

Because an open-ended approach to restoration is not predicated on an *a priori* vision for the ecological outcomes, it mirrors long-term ecosystem behavior with disturbance and change at small and large spatial and temporal scales (Willis and Birks 2006). Change may not always be gradual but stepwise, sudden and irreversible (Eppinga et al. 2009) and species may come and go over short or long time frames (Seppä et al. 2008). Relationships between biotic and abiotic components and processes in a locale change over time. An open-ended approach fits with recent trends in ecosystem science that conceive of ecosystems as integrated sets of processes operating over different spatial scales in non-equilibrial systems, rather than as particular organisational levels within a geographically delimited area (Currie 2011; Mori 2011).

When is Open-Ended Restoration Appropriate?

Following Higgs and Roush (2011), we offer a simple model to indicate when open-endedness is likely to be appropriate (Table 1) and then explore each factor in turn.

1. In Remote Areas

This is the context described by Higgs and Roush (2011). They conclude that an important goal of remote landscape restoration is to maintain remoteness and that allowing trajectories of change, whether or not they already incorporate identifiable elements of degradation, is an appropriate approach. This is highly relevant to contexts such as alpine environments facing the prospect of changing temperature regimes and altitudinal zonation under anthropogenic climate change (e.g. remnant arctic-alpine communities on Scottish mountains).

2. In larger restoration areas

An open-ended approach to restoration becomes more appropriate as the spatial scale of restoration projects increases because there is more scope to adopt lower levels of management intervention and to allow ecological processes to dictate outcomes. The levels of uncertainty in terms of which habitats will develop and where and which species will occur will also increase as a wider range of biophysical conditions and ecological processes become included (Hilderbrand et al. 2005) and due to the stochastic nature of processes. This is especially true if projects involve the re-mobilization of disturbance regimes such as flooding regimes following the removal of dams or weirs. The diversity of habitats produced (including novel habitats) will increase the chances of species finding a suitable functional niche to use, an increasingly valuable feature as species move in response to climate change.

3. Where future climate is predicted to change ecological limiting factors

The impact of human interventions on biogeochemical processes, especially in changing climatic patterns, is large and difficult to predict at the scale of most restoration projects. These challenges will increase in future. In response to anthropogenic climate change, species will adjust their range as they have done in the past or become locally, regionally or globally extinct. We can thus anticipate novel species assemblages at different spatial scales (Hobbs et al. 2006) moderated by novel competitive relationships with new species sometimes performing familiar functions (Davis et al. 2011). However, while these uncertainties will affect all restoration projects, they are most significant where future climate impacts are expected to most affect ecologically limiting factors. For example, in the East Anglian region of the UK it is predicted that rainfall will be reduced by 30% under both low and high emissions scenarios by 2050 (Hulme et al. 2002) leading to water deficits for wetland restoration.

4. Where conditions that gave rise to an apparent reference system cannot be repeated

Contemporary ecosystems are strongly influenced by antecedent environmental conditions. For example, the legacies of Holocene climatic change are still visible in forest and peatland habitats in NW Europe (Godwin 1939) and North America (MacDonald 1987) as are the more recent variations in precipitation and growing season of the Little Ice Age (Grove 1988). Restoration outcomes framed in terms of either contemporary or past reference systems are thus unlikely to be attainable under current environmental conditions (Hughes et al. 2005) even if anthropogenic climate change did not exist. Chosen reference habitats may even reflect past human degradation events, for example, floodplain woodlands on the Red Deer River, Canada, greatly expanded in extent following floods with high rates of sediment delivery associated with upstream logging in the late nineteenth century (Cordes et al. 1997). Where human management has played a role in the evolution of reference systems and species niches, it may be impossible to replicate the exact land management practices that formed the reference system because these may have varied over the last several centuries e.g. the grazing and regeneration patterns in wood pastures in the UK, or are not sustainable e.g. peat cutting. The plausibility of reference systems as a template for restoration thus decreases the more their contemporary state owes to previous environmental conditions or to previous human land-use practices that can no longer be replicated.

5. Where starting points are human-derived and novel

Where the starting point for restoration is novel, novel ecosystems can again be expected to develop (Seastedt et al. 2008). Thus derelict industrial sites or land used for intensive agricultural production may be so profoundly transformed in soil conditions that they can never support an ecosystem similar to any past reference state. Continuing levels of ambient pollution (e.g. airborne nitrogen or high levels of phosphorus in groundwater) may make re-establishment of key features of reference systems impossible. There are numerous urban or post-industrial restoration situations (e.g. industrial spoil tips or land contaminated with radioactive elements) where essentially an open-ended approach has been taken with no expectations of a return to previous conditions, although specific restoration interventions can reduce the level of pollution (Dobson et al. 1997). The presence of many alien species, for example on ex-agricultural land is now so widespread that it is unrealistic to exclude them from future habitat scenarios (Stroh et al. 2012).

6. Where restoration is strongly dependent on processes outside the restoration area

Many restoration projects depend on conditions and processes occurring outside the immediate restoration site. An open-ended approach may be appropriate where these processes cannot be predicted or controlled with sufficient accuracy that restoration to a specific target condition is achievable; for example in wetland restoration the quantity and quality of water may depend on conditions in the wider water catchment over which restoration managers have no influence. Other external influences may have more wide-reaching sources such as climate change or atmospheric pollution (Parker 1997).

7. In systems that are naturally very dynamic

Dynamic systems are often best restored by restoring the geomorphological or ecological processes that drive habitat change (e.g. in more physically active systems such as coastal and floodplain systems). However, the associated uncertainty suggests that an open-ended view of likely ecological outcomes has necessarily to be taken. For example, in the field of riparian forest restoration, considerable progress has been made with restoration of hydrological and sedimentological processes on which many floodplain forest species depend for their regeneration. Such restoration has been carried out both at a catchment-scale, in the form of planned flood releases from dams on regulated rivers (e.g. Rood et al. 2003), and at individual floodplain sites whose river embankments have been breached to enable localized flooding processes (e.g. Scheimer et al. 1999). This has been seen as a self-sustainable but less predictable approach to restoring riparian habitats, especially in terms of where along the river forest regeneration may take place and recognizes that riparian systems are often strongly non-equilibrial and therefore inherently open-ended in their evolution. In many cases it is technically difficult to do more than partially re-instate biophysical processes, e.g. Hall et al. (2011) describe restoration of a down-scaled flood regime on the Bridge River in British Columbia, Canada and partial restoration of river function and riparian forest regeneration. Here an open-ended approach to conceiving of restoration outcomes is appropriate since the scale of biophysical processes is novel.

8. Where cost of intensive restoration and ongoing management is high

Where the cost of highly prescriptive restoration is high it may be better value for money to use an open-ended approach. Although the uncertainty of the ecological outcomes under an open-ended approach will be higher it may prove more sustainable both in terms of providing habitat for a wide range of species and financially. In general, taking an open-ended approach involves low levels of initial habitat engineering and low levels of ongoing habitat management.

9. Where the public demands 'wildness'

While some restoration projects involve successful public education, most restoration projects reflect the views of government and public about what species and habitats are desirable. The general public is often conservative, desiring certainty of outcomes (often in the form of charismatic species) rather than changing outcomes. However, public perceptions of the relationships between humans and ecosystems change. In both Europe and the USA there is some public demand for a a lack of management intervention and a sense of 'naturalness' or 'wildness' (e.g. Taylor 2005), notwithstanding the complexity of these terms (Ridder 2007). Projects that have responded to this public need, such as Oostvaardesplaasen in the Netherlands and the Wicken Fen Vision in the UK, are, by their philosophy, open-ended in their approach to restoration. They may offer a robust approach to the challenges of future climate change. Such projects also introduce a series of parallel questions about how far public, government and other actors are willing to accept environmental variability and risk (e.g. introduced birds of prey or predators, or flooding)

10. Where there is limited knowledge of existing ecosystem patterns and processes

Many restoration projects have been developed in countries such as the UK or USA or Australia with a long history of ecological research, extensive current capacity for palaeoenvironmental research, survey and modeling, and a large and highly trained amateur naturalist sector. These countries are often mapped at a small scale, and there is extensive knowledge available to plan restoration strategies. Where restoration is attempted in countries without these advantages, conventional strategies based on specific targets and reference systems may not be possible, and an open-ended approach may be more appropriate. This may be particularly true where the system being restored is extensive or poorly understood. An example is the attempt to grow back 700 km^2 of tropical dry forest at Guanacaste in Costa Rica (Allen 2001; Calvo-Alvaradoa 2009).

Discussion

In this paper, we have outlined contexts in which we consider an open-ended approach to restoration to be appropriate. It might perhaps be argued that an open-ended approach should not be considered a form of ecological restoration at all. However, we believe it falls within standard definitions of restoration (e.g. SER 2004, p.1: an 'intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability'), focused on recovery of ecological processes rather than of some pre-disturbance state. We would emphasize that an open-ended approach to restoration should not be used as an excuse to replace target-driven restoration where such an approach is necessary or desirable.

The uncertainties associated with an open-ended approach to restoration present challenges to project managers. First, there is likely to be a need for managers to explain the project and deal with public expectations and perceptions of risk. This is particularly necessary at the outset but remains an important ongoing activity. Second, it may be harder to obtain finance from conservation funders used to project proposals that specify predictable ecological outcomes. Third, monitoring and periodic project assessments are particularly important in open-ended restoration projects so that change is measured and understood: open-ended restoration does not mean 'abandon and ignore it'. Monitoring should involve 'status assessment' (Stem et al. 2005), focused on keeping track of changing biophysical processes, species arrivals (and extinctions) and changing provision of ecosystem services (Hughes et al. 2011).

Implications for practice

- Open-ended approaches to ecological restoration are appropriate in some contexts but care should be used when choosing this approach over target-driven approaches.
- Open-ended restoration project aims should be framed in terms of change rather than achievement of specified species or habitat targets. Management plans and monitoring programmes should reflect this.
- Open-ended restoration needs to be carefully explained to all stakeholders, especially in the light of public expectations and perceptions of risk.

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Table 1 **Factors Demanding Open-Endedness in Restoration**

Open-endedness less appropriate	**Factor**	**Open-endedness more appropriate**
Low	1. Remoteness	High
Small	2. Size of Area	Large
Low	3. Uncertainty over impact of anthropogenic climate change to ecological limiting factors	High
High	4. Plausibility of reference system	Low
Low	5. Novelty of starting point	High
Low	6. Dependence on processes external to restoration site	High
Low	7. Level of ecosystem dynamism	High
Low	8. Restoration and management costs	High
Low	9. Human acceptance of ecosystem change	High
Good	10. Knowledge of existing ecosystem patterns and processes	Poor