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OPINION ARTICLE

Multiple meanings of history in restoration

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In ecological restoration, the role of *historical fidelity* in restoration references has long been both a foundational concept and a frequent source of debate. However, this is not the only role that history plays. History in the sense of *historical knowledge* can inform goal-setting and provide tools for success. History in the sense of *historical events* (what has happened in a place) in many ways determines the goals and trajectories of restoration, and to what extent a historical reference is knowable and applicable. Here, we discuss a conceptual framework for how these forms of "history" interact, and particularly the underappreciated ways in which historical events shape the aspirations and limitations of restoration. We propose that considering legacies of historical events in the who, when, and where of restoration will be crucial to informing appropriate restoration goals for the future.

Key words: ecological restoration, ecosystem management, goal-setting, historical knowledge, legacies

Conceptual Implications

- Restoration often uses historical knowledge as a basis for setting goals informed by the past. However, we gain a more complete perspective by considering also how past events have had lasting impacts on what we know and what we are able to accomplish.
- Interrogating what we know about the past, and how, should guide restoration even when the goal is not to restore to a past ecosystem state.

Introduction

What should history mean in restoration ecology? The historical reference has long been a central concept in restoration, and also a frequent subject of debate (Balaguer et al. 2014). Restoration goals have often been framed in terms of *historical fidelity*: returning an ecosystem to the species composition, ecosystem structure, or function of the past (Hallett et al. 2013). At the same time, restoration is also a forward-looking field, focused on active intervention for a better future (Choi et al. 2008; Hobbs et al. 2011; Pape 2020). Critiques of the historical reference are numerous—with some highlighting that threshold dynamics may make it impossible to achieve historical fidelity (Hobbs et al. 2014, 2009) and others emphasizing that the inherent variability of ecosystems through time, and long histories of human influence, complicate the choice of time scale and context for defining a reference (White & Walker 1997; Balaguer et al. 2014; Gann et al. 2019). As such, some have called explicitly for restoration to look "toward the future, and not the past" (Pape 2020).

Going forward, we argue that restoring for the future need not mean looking away from the past, but rather the appropriateness of *historical fidelity* (the extent to which the goals of restoration are based on an ecosystem's past) should be considered in the context of two other key meanings of history: *historical knowledge* and *historical events*. Here, *historical knowledge* means scientific and cultural knowledge regarding prior ecosystem conditions and variability, past socio-ecological interactions, and the extent of ecological change. Such knowledge plays multiple important roles in informing goals, methods, and values of restoration (Higgs et al. 2014; Beller et al. 2020). At the same time, we must consider the impact of *historical events*: all that has happened in a place, known and unknown. This can mean layers of past ecological dynamics and land management decisions, as well as histories of land tenure and responsibility that have shaped ecosystems and cultural perspectives of them. Whether we recognize them or not, past events set the terms for how other forms of history are used in restoration: influencing the accessibility of knowledge as well as the attainability of historical fidelity.

Here, we propose that considering how each of these forms of history interact (Fig. 1) can bring greater clarity to the complexities of restoring for the future. We briefly review the connections between each of these meanings of history in restoration, working backward from the interplay between historical knowledge and fidelity, and then outline a framework for how to use

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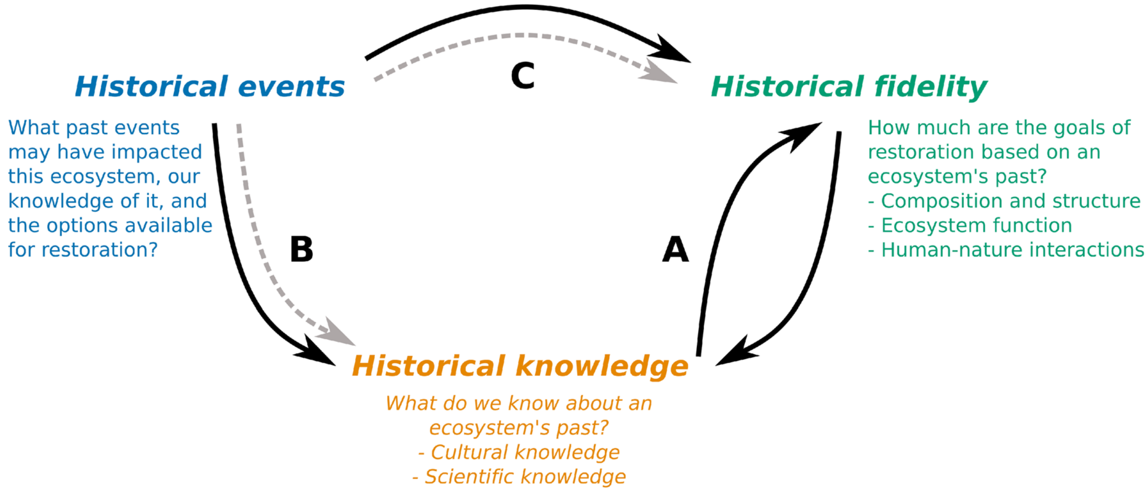

Figure 1. Linkages between three meanings of history in restoration. “Historical events” refer to past events in an ecosystem (whether known or not). “Historical knowledge” refers to scientific and cultural knowledge about an ecosystem’s past. “Historical fidelity” means the extent to which the goals of restoration are based on an ecosystem’s past. The linkages between these forms of history (A, B, and C) are discussed in the text. The two-way arrows between historical knowledge and fidelity (A) indicate the possibility of feedbacks, where historically informed restoration can further strengthen and grow knowledge of the past. The black and gray arrows from historical events to knowledge and fidelity (B and C) suggest the incompleteness of knowledge about the impacts of past events, which may influence current knowledge and actions whether fully recognized (black arrow) or not (gray arrow).

this broader perspective on history in determining restoration goals.

Feedbacks Between Historical Knowledge and Historical Fidelity

Historical fidelity in restoration is necessarily linked to historical knowledge (linkage A, Fig. 1). Incorporating the past into the definition of an appropriate reference model depends on accurate knowledge of past ecosystem characteristics and variability (Swetnam et al. 1999; Balaguer et al. 2014; Higgs et al. 2014). Historical knowledge also guides methods of restoration; understanding historical disturbance regimes, e.g. may inform the use of disturbance as a tool, such as the use of burning, mowing, or raking in restoring disturbance-dependent grasslands (MacDougall & Turkington 2007). Moreover, restoration action can itself feed back on historical knowledge by creating opportunities to learn or to strengthen existing knowledge (linkage A, Fig. 1). Beyond serving as an “acid test” of ecological theory (Bradshaw 1987), studying restored landscapes can yield new insights about how such landscapes functioned in the past, and reinforce past knowledge that might otherwise have been lost. Dam removals, e.g. have enabled new research programs that will inform a better understanding of how river ecosystems previously functioned (Woodward et al. 2008). Restoration using Indigenous burning practices in Pacific Northwest prairies, informed by historical ecology and ethnography, has allowed for further contemporary study of relationships between fire and camas (*Camassia quamash*) productivity (Storm & Shebitz 2006). The feedback loop between historical knowledge and the application of a historical reference is thus a form of adaptive management, where management action facilitates further learning (Murray & Marmorek 2003).

Feedbacks between historical knowledge and historical fidelity are particularly important in restoring human connections to ecosystems, such as through the integration of traditional ecological knowledge in restoration. Knowledge informs historical fidelity: Indigenous and local peoples have maintained ecosystems for millennia, and their historical knowledge illuminates not only what ecosystems have looked like in the past but also what management practices and cultural values should guide the goals of restoration (Kimmerer & Lake 2001; Senos et al. 2006; Long & Lake 2018). At the same time, historical fidelity in ecological restoration feeds back on the maintenance and renewal of cultural knowledge. Restoration informed by the past creates opportunities to reinstate historical stewardship practices, rebuild relationships between people and place, and maintain traditional knowledge through continual interaction with the ecosystem, where such connections had previously been lost (Senos et al. 2006; Turner & Turner 2008; Long & Lake 2018).

Influence of Historical Events on the Accessibility of Historical Knowledge

Historical knowledge is clearly valuable to restoration, but we must also consider how historical events have shaped or biased the availability of knowledge (linkage B, Fig. 1). The clarity or obscurity with which humans see the past is, itself, a matter of history. The commonly cited “shifting baselines” issue in conservation and restoration, where ecological understanding is based on a past reference that was already degraded, is a problem of historical discontinuity of knowledge, and turnover in lived experience (Knowlton & Jackson 2008). Individually, every person brings their own baseline of experience to bear on attitudes about nature. Drawing out these unspoken histories, and their influence on ecological values and perceptions, can help to reconcile conflicting goals in restoration (Hobbs et al. 2004).

Historical knowledge is often incomplete not only because of the limitations of lived experience in a changing world, but because knowledge has been destroyed out of acts of power. Histories of oppression have repeatedly obscured, marginalized, or obliterated historical understanding of ecosystems, with damaging consequences for people and nature. One example is the mischaracterization of tropical grasslands and savannas as "degraded forests," based in the biases of European colonizers and the erasure of local knowledge (Ratnam et al. 2016). When these ecosystems are targeted for afforestation on a global scale, this is often framed as "restoration," when in fact it has the effect of destroying native ecosystems (Bond et al. 2019). Similarly, Indigenous knowledge of issues such as the active use of fire for ecological management, though increasingly recognized by the scientific establishment today, has long been marginalized and ignored, or lost as the bearers of knowledge were killed or displaced from their land (Kimmerer & Lake 2001; Trauernicht et al. 2015). Reckoning with these histories is crucial to establishing a more ethical relationship with the past while also seeking a more accurate understanding of ecosystems (Senos et al. 2006; Long & Lake 2018; Reyes-García et al. 2018).

Ecosystems also keep records of their own pasts, but some records are more legible than others, depending on the intervening influence of historical events. Determination of a reference model often relies on finding sites representing more intact versions of the site to be restored (White & Walker 1997; Gann et al. 2019), but the more extensive the history of degradation across a landscape, the scarcer and less relevant nearby habitat refugia may be (Schaefer 2009). The availability of other sources of historical and paleoecological information also vary with the ecological and human history of an area. Tree rings, e.g. are a rich source of information on past disturbance regimes and climatic variability (Swetnam et al. 1999; Manzano et al. 2020), but only if the trees or logs are still there.

Impacts of Historical Events on Attainability of Historical Fidelity

Historical events can also directly impact the feasibility of achieving historical fidelity (linkage C, Fig. 1). Past events set the stage for how challenging degradation may be to reverse, and whether key thresholds have been crossed to new ecosystem states. Histories of land use and biological invasions have lasting biotic and abiotic legacies, such as changes in soil communities or hydrology, that may aid or hinder restoration efforts (Schaefer 2009). Even well-intentioned past efforts at restoration can impact future restoration projects, such as where previous strategies were more targeted at restoring a particular ecosystem function than restoring native species. Examples include crested wheatgrass plantings in the Great Basin to improve rangeland condition after overgrazing (Svejcar et al. 2017), and plantings of non-native trees for rapid afforestation (Wang et al. 2013). The legacies of these strategies can impede later attempts at native species restoration, and may have other unintended consequences as well, such as planted trees depleting groundwater (Cao et al. 2011).

Historical events have policy legacies as well; one example of this is evident in weed control laws in the Western United States. Cheatgrass (*Bromus tectorum*), one of the most problematic weeds in the Intermountain West, is not registered on noxious weed lists, as it is considered *too* widespread for policy to require aggressive control everywhere it is found (Pyke et al. 2016). Because of the timing of its arrival as an invader, relative to the human history of managing it as such (Knapp 1996), cheatgrass managed to cross a crucial policy threshold—in addition to ecological feedbacks that reinforce its dominance (Chambers et al. 2007; Balch et al. 2013). None of this necessarily precludes intervention, but the layers of social and ecological history surrounding this species, as with many prolific invasive species, influence the magnitude of the challenge.

Decision-Making About the Role of History in Restoration

The degree to which restoration goals emphasize historical fidelity should depend on who, when, and where: the agent of

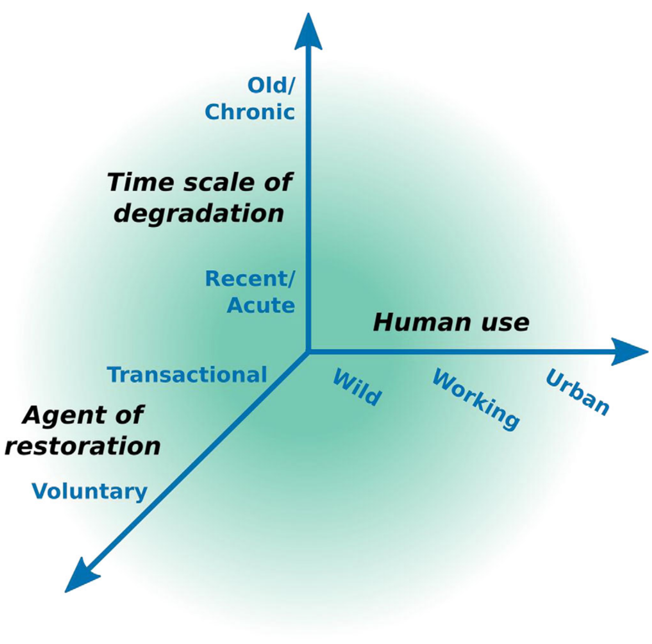

Figure 2. Framework for decision-making about the use of history in restoration goals. All three axes (human use, time scale of degradation, and the agent responsible for restoration) are influenced by past events. These factors in turn influence the feasibility and desirability of historical fidelity (shown as green shading, as in Fig. 1). Where green shading is heaviest, strict historical fidelity may be most appropriate; where shading is lightest, restoration may be less targeted at returning to a historical state, but nevertheless informed by historical events and knowledge.

restoration, the time scale of degradation, and the intensity of human land use, each of which are rooted in historical events (Fig. 2). The "who" matters because we set a more stringent standard for transactional restoration, where the same agent (such as an industrial polluter) that has benefited from the degradation is responsible for fixing it (Gann et al. 2019); voluntary restoration, decoupled from culpability, may still aim for historical fidelity but should be allowed greater flexibility in its goals. Meanwhile, the time scale of degradation (the "when"), and the land-use context past and present (the "where"), both impact the magnitude of ecological and social legacies that may stand in the way of achieving historical fidelity.

These axes need not be correlated; a heavily used urban site, e.g. could be only recently degraded (Fig. 2). As an example to illustrate the extremes, we may have the highest expectations for historical fidelity under mandated restoration of recently disturbed mining sites in wilderness (Gann et al. 2019). Alternatively, stream restoration by volunteers in an urban setting that has been highly modified for hundreds of years may, realistically, have goals that account for the unlikelihood of completely eradicating invasive species, and adjust accordingly (Hallett et al. 2017). At neither of these extremes, however, is "history" irrelevant. Historical fidelity may be diminished in importance as a *reference* precisely because of the legacy of intervening historical *events*. Furthermore, historical fidelity is not all-or-nothing; even where goals such as restoring historical species composition are infeasible, restoration goals can still incorporate knowledge of past ecosystem function and cultural values.

Many ecosystems and restoration projects will fall at intermediate points on these continua (Fig. 2), where historical events and their legacies have determined, to varying degrees, the feasibility and desirability of historically based goals. In such cases we may see the greatest conflicts over objectives; such as in mixed-use landscapes with complex land-use histories, where some degree of restoration to historical conditions is achievable but comes at a cost, and where stakeholders diverge in priorities (Paschke et al. 2019). Understanding the role of history in restoration will not, on its own, resolve such questions of values. However, a collaborative assessment of layers of underlying history can help move these conversations forward. As such, we propose a set of guiding questions tied to the linkages shown in Figure 1:

(1) How have historical events in this system shaped the range of possible outcomes and restoration goals? (linkage C)
(2) How have historical events informed or obscured knowledge of this system? (linkage B)
(3) How can our historical knowledge guide the definition of restoration goals and methods, and how can restoration action be designed to feed back on knowledge? (linkage A)

Where to Go From Here

Restoration, ultimately, is defined by the future we envision for ecosystems, in the face of new challenges but also opportunities (Choi et al. 2008; Hobbs et al. 2011; Pape 2020). The rapid pace of global change will continue to alter ecosystems worldwide, and reference models will need to adjust accordingly; in this sense, we can expect the goals of restoration to increasingly diverge from historical fidelity (Hobbs et al. 2009, 2014). At the same time, the future of ecological restoration presents new opportunities to move beyond the limitations and legacies of past events, and in so doing, perhaps gain greater access to features of historical ecosystems we wish to restore. Some of these opportunities will be technological; research continues to produce innovations, such as novel seed technology (Pedrini et al. 2020), that make restoration possible where change had previously seemed irreversible. There is also hope in the ways that restoration ecology increasingly values voices that were previously excluded: incorporating traditional knowledge in the goals and practices of restoration, and engaging local stakeholders in decision-making, will set the stage for restoration to be part of a more just and equitable future (Senos et al. 2006; Gann et al. 2019; Paschke et al. 2019; Pape 2020). Historical knowledge in its many forms will continue to be essential to restoration planning even when the goal is not to restore to a past ecosystem state (Higgs et al. 2014; Beller et al. 2020). Overall, a holistic view of multiple meanings of history, and the questions this framework raises for decision-making, will help in establishing a clear vision for this Decade on Ecosystem Restoration and decades to come.

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