doi.org/10.22498/pages.30.1.3

Mainstreaming paleoecology into ecosystem restoration

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2021 marked the beginning of the United Nations Decade on restoration ecology. Restoration of ecosystems is essential in slowing biodiversity loss and associated erosion of ecosystem services. However, defining restoration goals in an uncertain and changing world raises fundamental questions of what we are restoring and why. The purpose of this special issue is to explore the contributions of paleoecology in addressing these questions and to encourage better integration of paleoecology into restoration ecology and conservation planning.

What are we restoring?

The most obvious–and yet still underutilized–use of paleoecological data in restoration ecology is to provide reference conditions, especially in ecosystems that have experienced significant anthropogenic degradation over periods of time that extend beyond living memory or historical records (e.g. Finlayson and Gell p. 10; Marcisz et al. p. 12; Hapsari et al. p. 14). Paleoecological data sometimes reveal surprises regarding the extent and composition of vegetation in the past, showing that current vegetation is in fact far from natural, and confirming or rejecting the status of alien species (Nogué et al. p. 4; Wilmshurst and Wood p. 26). Although "naturalness" is a contested term, areas with minimal or light human impact are, nevertheless, an important landscape component in many regions (e.g. Nanavati et al. p. 22; Morales-Molino and Schwörer p. 6; Rull p. 18; Finsinger et al. p. 8). Restoration of desired cultural landscapes can also have benefits to both biodiversity and people (see Rull p. 18).

Even without significant human impact, most landscapes are dynamic and respond to multiple interacting environmental drivers, including changes in climate, disturbance, land use, and biotic interactions. Understanding the long-term importance of fire and herbivory, for example, is an important scientific contribution from paleoecology, particularly as it relates to climate extremes, land abandonment, and rewilding (Higuera et al. p. 30; Morales-Molino and Schwörer p. 6). Interactions among environmental, biotic, and anthropogenic drivers can also cause shifts between alternate stable states. This is especially likely at ecotones (vegetational transitions), which are sensitive to subtle changes in climate, fire, and land use and therefore present particular challenges for restoration (Nanavati et al.p. 22; Giesecke et al. p. 24).

Why are we restoring? From static "baselines" to dynamic processes

In today's changing world, no-analog climate conditions are increasingly likely in the coming decades, and a return to "natural" conditions may be impossible or undesirable. As a result, there has been a shift in restoration ecology towards a broader range of conservation objectives that considers the degree of past anthropogenic modification, as well as the desired ecosystem function or condition (Chambers p. 16; Rull p. 18). Considerations include which ecosystems will be most vulnerable to future climate and land-use change and which should be prioritised for restoration and conservation actions (Adeleye et al. p. 28; Higuera et al. p. 30). Paleoecology can also guide efforts to maintain critical ecological functions, such as pollination, by revealing unsuspected past interactions in species whose ranges are currently disjunct (Wilmshurst and Wood p. 26). The integration of paleoecology into an inclusive, process-based approach to restoration ecology is illustrated in Figure 1. Note that as the future is uncertain, the implementation approach needs to be adaptive.

Conclusions and ways forward

The papers in this issue demonstrate a huge and largely untapped synergy between the disciplines of paleoecology and restoration ecology. Ensuring that this potential is realized will require a concerted effort by the paleoecological community in seven main areas:

- Better calibration of paleoecological datasets to increase their usefulness as reference frameworks for conservation planning.
- Wider incorporation of new techniques, such as ancient DNA/sedimentary DNA, to document past changes in biodiversity (e.g. see Wilmshurst and Wood p. 26).
- Communicating paleoecological findings in an applied context, wherever possible, so that the information is accessible and available to the restoration ecology community and beyond.
- Greater integration of paleoecology with other disciplines and knowledge streams, including traditional ecological knowledge (see Gil-Romera et al. p. 20 and the special section in this issue "Socio-ecological approaches to conservation" p. 33).
- Showcasing the relevance of historical perspectives in process-based thinking and modeling efforts that guide adaptive management planning for emerging conditions and societal preferences (e.g. Morales-Molino and Schwörer p. 6).
- Validating dynamic modeling outcomes, for example, by comparing sedimentary proxy data with simulations of ecosystem changes in response to climate change, disturbance, and land use.
- Encouraging managers and policy makers to think on time scales longer than a few decades so that paleoecological information becomes routinely incorporated into landscape conservation planning (e.g. the Ramsar Convention; see Finlayson and Gell p. 10; Hapsari et al. p. 14; Chambers p. 16).

The paleoecological community has a vital challenge ahead: that of seamlessly integrating paleoecology and neo-ecology, thereby enabling the mainstreaming of paleoecology into restoration ecology and biodiversity conservation.

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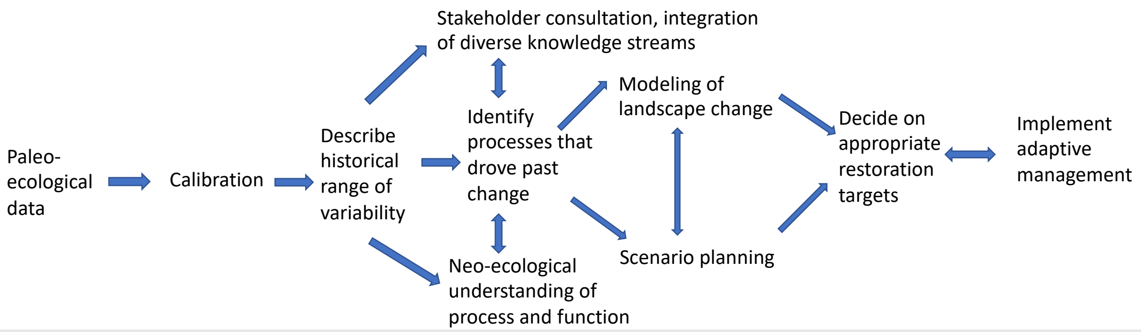

Figure 1: A suggested framework by which paleoecology could be integrated with other disciplines and knowledge streams in a process-based approach to restoration ecology that includes science, modeling, stakeholder consultation and adaptive management.