Biological Conservation 176 (2014) 12–20

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Perspective

The historical reference in restoration ecology: Re-defining a cornerstone concept

Luis Balaguer [a,1], Adrián Escudero [b,*], José F. Martín-Duque [c], Ignacio Mola [d], James Aronson [e,f]

[a] Department of Plant Biology I, Complutense University, Madrid 28040, Spain
[b] Department of Biology and Geology, Rey Juan Carlos University, Móstoles 28933, Spain
[c] Department of Geodynamics, Complutense University of Madrid and Institute of Geosciences, IGEO (CSIC, UCM), Madrid 28040, Spain
[d] Research, Development and Innovation (R&D) Service, Obrascón Huarte Lain, S.A. (OHL), Madrid 28046, Spain
[e] Centre d'Ecologie Fonctionnelle et Evolutive (CNRS-U.M.R. 5175), Montpellier 34293, France
[f] Missouri Botanical Garden, St Louis, MO 63110, USA

ARTICLE INFO

Article history:
Received 28 December 2013
Received in revised form 29 April 2014
Accepted 4 May 2014

Keywords:
Ecological memory
Ecosystem trajectory
Geoarchaeology
Geomorphological reference
Historical continuity
Sequential reference model

ABSTRACT

Ecological restoration aims to revitalize ecosystem integrity and functionality following severe damage or degradation. Often, however, efforts are hampered by an incomplete or flawed concept of historical 'reference' used when choosing or constructing a target ecosystem or landscape to restore 'to'. This problem may stem from a culturally-skewed interpretation of history or from misunderstanding or underestimation of the role that humans have played in a given ecosystem's historical development and dynamics. While strongly confirming the importance of the reference concept in restoration ecology, we argue for the need to refine it, and to broaden the ways it can be conceived, developed, and applied. Firstly, the historical reference system informing a given restoration project should be grounded in both latent and active 'ecological memories', encoded and stored across relevant geographical and temporal scales. Further, the generally neglected geomorphic component of reference-building should also be addressed, as well as the contributions of human cultures to current ecosystem and landscape condition. Thirdly, ecosystems are historically contingent and multi-layered. Pre- versus post-disturbance comparisons are insufficient. Instead, restoration scenarios should be seen as tapestries of multiple and successive states. In sum, a well-conceived reference model helps promote and ensure the recovery and subsequent maintenance of historical continuity, i.e., the reestablishment of an impaired ecosystem to its historic ecological trajectory. We use case studies from Spain and Peru to illustrate how this approach can provide better goalposts and benchmarks, and therefore better guide the planning, implementation, and evaluation of effective restoration projects.

Contents

* Corresponding author.
E-mail address: adrian.escudero@urjc.es (A. Escudero).

[1] Tragically, our dear friend Luis Balaguer passed away on March 19, 2014, just shy of his 50th birthday. We dedicate this contribution to his memory.

http://dx.doi.org/10.1016/j.biocon.2014.05.007

The past is never dead. It's not even past.
William Faulkner (1951, *Requiem for a nun*)

1. Introduction

Twenty years ago, Wilson (1992: 340) famously wrote: *The next century will, I believe, be the era of restoration in ecology*. Today, the science, politics, business, and practice – both professional and amateur – of ecological restoration are recognized as a global priority (CBD, 2012; Aronson and Alexander, 2013a, 2013b). Ecological restoration appears to be one of the most promising strategies for renewing ecosystem integrity and functionality in areas where degradation and transformation have gone too far, or gone awry (Young et al., 2005; Devoto et al., 2012). It also appears to be a galvanizing concept, and meeting place, for widely disparate interest groups and stakeholders looking for new models, new directions, new paradigms (Murcia and Aronson, 2014).

However, thirty years after the emergence of ecological restoration as a scientific discipline, and professional vocation, many people question whether restoration in general, and the selection of an historically-based reference system in particular, are relevant or practical in today's rapidly changing world (e.g., Hobbs et al., 2009). According to this line of reasoning, it is very often futile to try to restore past conditions; instead we should focus on promoting, managing, and molding 'novel' ecosystems (sensu Hobbs et al., 2006) to provide as much and as many desired ecosystem services as possible (Millar et al., 2007. Much has been written about this issue (e.g., Simberloff and Vitule, 2014), and we will not address it in detail here. Suffice it to say that we do not accept this argument and that, despite substantial literature on the subject (see White and Walker, 1997; Egan and Howell, 2001; Clewell, 2009; inter alia), in the novel-ecosystem literature, and indeed generally in restoration ecology, conservation science, and related fields, much confusion persists with regards methodology, scope, and application of the reference concept. In our view, this remains the cornerstone concept, and conceptual tool that distinguishes ecological restoration from other related activities.

In this paper, we argue that the improvement in understanding, and use, of the concept of a reference model, can contribute significantly to make ecological restoration more relevant, understandable, and effective viable as a new paradigm, in social, economic, and cultural terms. In particular, we focus on the need to identify, select or construct *locally-tailored* historical references, using all the available and appropriate conceptual tools, so as to integrate both latent and on-going ecological and socio cultural processes and values. Among them, we will consider, especially, the geomorphic and the human-cultural processes that are all too often neglected or mishandled when selecting or constructing a reference model. We consider the conceptual tools and the methodological techniques needed to select or construct the best possible historical reference. We recall that each and every biotic community is formed by species originating at different geological periods that co-occur transitorily as the outcome of sorting processes and historical effects (Herrera, 1992). Their assembly, and, fortiori, their reassembly, is an historically contingent process (Fukami et al., 2005), contingent very often on human land use history, among other factors (Balée, 2010). Attempts at reassembly should be approached not only with regard to theoretical community ecology and so-called assembly rules theory (Temperton et al., 2004), but also in the context of an historical sequence and *ecosystem trajectory* (Aronson et al., 1993), which also involves human land use changes, physical processes and landform dynamics (Collins et al., 2012).

Using recent case studies from Peru and Spain iwe attempt to illustrate the application of the historical reference concept, and to show how an expanded, operational reference not only provides goalposts and benchmarks, but also informs planning, implementation, and evaluation of restoration projects that aspire to long-term effectiveness, success and broad-scale impact.

2. The role of the past in the construction of the reference

In ecology, as in human psychology (cf. Rathus, 2000), memory is the process by which the historical sequence of past events is encoded, stored, and retrieved. History, applied to ecosystems, remains encoded or imprinted, through its ecological consequences, in the assemblage and dynamics of the ecosystem mosaic, in what has been termed 'ecological memory' (Thompson et al., 2001). We argue that ecological memory should not be seen as a passive legacy. Rather, it is an active morphogenetic agent and indeed a primary driver for current and future ecosystem configurations and functioning.

The 'strength' of ecological memories has been defined as the extent to which ecological structure and processes are shaped by their history (Peterson, 2002). Although this strength has been attributed only to biotic drivers, and the effects of past disturbance, ecological memory is also stored in landforms and in topographic heterogeneity, which are shaped by geomorphic and hydrological processes (Larkin et al., 2006). Additionally, social and cultural memory nurture ecological memory to the extent that human activity interacts with, and partly determines, repositories and drivers of ecological memories, such as microclimate, landscape configuration, and soil structure and composition (Olsson et al., 2004). All these components are interwoven in ecological memory, not as a local collection of vestigial structures, but rather as a reservoir in continuous recombination and re-definition. In socio-economic terms- which are an essential correlate to the ecological sciences approach to restoration -, the ecological memory is a inventory or inheritance under constant review. Finally, in philosophical and literary terms, it is a palimpsest written again and again though space and time, but at different rates, depending on the spatial scale considered.

At a regional scale, geographical, geological and climatic aspects of ecological memories have been configured over millions of years. Memories at the landscape scale include those encoded by past human activities over centuries, sometimes millennia. At the local scale, ecological memories, such as soil-borne seed banks, may take form in just a few years (Olano et al., 2011).

The relevance of this reservoir of memories, this palimpsest for ecological restoration practitioners to read, resides in its role as the historical component of ecosystem and landscape resilience (Bengtsson et al., 2003). This dual nature of ecological memory—as both a legacy of, and a driver for, ongoing and future ecosystem changes—has not been sufficiently explored by those thinking and writing about ecological restoration (but see Schaefer, 2009), or those actually doing it. For instance, the role of biological legacies (e.g., remnant living organisms, seed banks, and organic structures and biotic patterns, sensu Franklin et al., 1985), as well as of the persistent effects (cf. 'biological inertia' sensu Von Holle et al., 2003) are often underestimated or overlooked. This bias is reflected in both aquatic and terrestrial ecosystem restoration projects whenever direct replacement, or reintroduction, of formerly present plant species by direct sowing or planting is undertaken as a knee-jerk reflex. In wetland ecosystem restoration, for example, evidence exists that revegetation is not the most effective approach available, either in ecological or economic terms (Moreno-Mateos et al., 2012). In tropical forest restoration, much evidence also suggests that assisted regeneration can occur from remaining tree cover, and seed or seedling banks (Harvey et al., 2008; Shoo and Catterall, 2013). As a third example, in heavily impacted sites slotted for re-greening, such as road or railway slopes, the widespread use of hydroseeding compares unfavorably with the spontaneous influx of wind-dispersed seeds from the surrounding landscape, provided remnant vegetation stands occur in