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REBUTTAL

Appropriate aspirations for effective post-mining restoration and rehabilitation: a response to Kaźmierczak et al.

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Abstract
Confusion surrounding the definition and application of terminology in post-mining ecological repair has resulted in uncertainty for industry, the scientific community and regulators. This lack of clarity may underrepresent high aspirations or could be misused to disguise low aspirations and so is problematic for setting objectives, establishing goals and assessing recovery trajectories. We respond to a recently published analysis of the ecosystem repair literature, where we highlight inconsistencies stemming from inadequate reference to a large proportion of the restoration and rehabilitation literature. We outline increasingly well-accepted and internationally applied definitions concerning the restoration and recovery process and invite both the mining industry and policy-makers to re-examine their terminology in the interests of attaining an internationally agreed nomenclature. Clarity in the use and understanding of terminology will align post-mining targets with community expectation, enhance the capacity of the mining industry to understand and meet these targets, and foster better analysis and more industry-relevant discussion of recovery methodologies by the scientific community and practitioners.

Keywords Ecological restoration · Ecosystem recovery · Ecosystem repair · Post-mining · Reclamation · Rehabilitation · Revitalisation

Introduction

In recent decades, there has been a major shift in social perceptions worldwide with regard to ecosystem recovery processes—both assisted and unassisted. This has been accompanied by recognition of the need for broadscale repair of degraded ecosystems and landscapes that often involves substantial investment (e.g. Clewell and Aronson 2013; Perring et al. 2015; Bustamante et al. 2016; Hobbs 2016). The phrase 'ecological restoration' is pivotal in this discussion (Clewell and Aronson 2013), yet there has been and continues to be widespread debate—often driven by confusion—regarding basic concepts, definition and application of ecological restoration in varying contexts. There is also an emerging tendency to conflate ecological restoration with other related activities that may or may not actually be a restorative action.

In a recent article, Kaźmierczak et al. (2017, p 2) correctly note that 'analysis of the literature connected to the issues of returning the utility and natural functions to the areas after mining ceases shows application of many terms which may be used differently and often even improperly'. In attempting to address this issue, the authors present a system of classification. They also propose standardisation of the terminology related to ecosystem recovery in the context of post-mining land use.

However, the attempt by Kaźmierczak et al. (2017) to rectify the issue of poorly defined terminology actually does the reverse, and indeed risks introducing further confusion into

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post-mining land management discussions. Kaźmierczak et al. (2017) overlook 25 years of scientific literature on the concepts, definitions, methodologies and economics of ecological restoration and rehabilitation. Further, they focus on final land use (which they describe as the 'land development phase'), without any discussion of the process-driven methodologies for attaining the target condition (i.e. which they describe as the 'reclamation phase').

Here, we respond to Kaźmierczak et al. (2017) by outlining broadly accepted definitions concerning the restoration and recovery *process* in a context where there are increasing expectations for restoration or rehabilitation of native ecosystems after mining. We also show that these definitions are being used effectively as a guide for land managers in a broad range of circumstances, including post-mine restoration and rehabilitation.

Words matter: call for clarity in definitions and their application

Confusion surrounding terminology has long hampered the effective interpretation and communication of academic studies in disciplines relating to environmental repair. Such confusion has reduced the appetite of regulators, legislators, industry and other end-users to engage and cooperate with the scientific community on resolving a common language in restoration (Stevens and Dixon 2017). Indeed, Stevens and Dixon (2017) suggest that overcoming the science–policy gap represents the most effective way to build restoration capacity. This would drive both environmental and cost efficiency improvements in ecological restoration in mine site closure.

Kaźmierczak et al. (2017) provide definitions for four terms they consider to occur most often in the literature related to environmental repair and management, namely 'restoration', 'rehabilitation', 'reclamation' and 'revitalisation'. However, comparison of these definitions with those of the Society for Ecological Restoration (SER) highlights a number of inconsistencies stemming from inadequate reference to a large proportion of the restoration and rehabilitation literature (Table 1).

Regarding the key terms restoration and rehabilitation, there are numerous competing definitions, as noted by Kaźmierczak et al. (2017). However, the International Standards for the Practice of Ecological Restoration (McDonald et al. 2016) that have been adopted by SER provides clarity in the use of restoration and rehabilitation (Table 1). This contemporary document, which is not cited by Kaźmierczak et al. (2017), builds on definitions presented in the SER Primer on Ecological Restoration (SER 2004), and the definition first adopted by the SER board in 1994 (Jackson et al. 1995). Surprisingly, these foundational documents are not cited by Kaźmierczak et al. (2017).

The authors cite an important, indeed seminal, paper focussed on ecological restoration (Bradshaw 1996). However, Kaźmierczak et al. (2017) neglect the extensive international literature surrounding the principles and conceptual development (e.g. Hobbs and Norton 1996; Harris et al. 2006; Jackson and Hobbs 2009; Clewell and Aronson 2013; Palmer et al. 2016), guidelines and theoretical advances (e.g. Keenleyside et al. 2012; van Andel and Aronson 2012; Perring et al. 2015), commentaries (e.g. Aronson and Alexander 2013; Hobbs 2016) and critical review (e.g. Rey Benayas et al. 2009; Suding 2011) of restoration ecology concepts and definitions published in the intervening period.

Table 1 Definitions for ecological restoration, rehabilitation, reclamation and revitalisation presented by Kaźmierczak et al. (2017) compared with the definitions for these practices proposed by the Society for Ecological Restoration in its widely cited Primer (SER 2004) and the more recent Standards documents (McDonald et al. 2016)

	Kaźmierczak et al. (2017)	SER (2004), McDonald et al. (2016)
Ecological restoration	'The process of the site condition replication after deposit exploitation', *also* 'the return to the original state of the altered land, the state before degradation'	'The process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed'
Rehabilitation	'The establishment of a stable and self-sustaining ecosystem, but not necessarily the one that existed before mining began', *also* 'the return to the utility/natural state according to the original land development plan'	'Direct or indirect actions with the aim of reinstating a level of ecosystem functionality where ecological restoration is not sought, but rather renewed and ongoing provision of ecosystem goods and services'
Reclamation	'Restoring or giving the usable values to degraded or devastated land by appropriate land modelling (ground works, slopes reinforcement), improvement of physical and chemical properties, water regulation, soils restoration and roads construction or reconstruction'	'Usually a return of the land to what is considered to be a useful purpose'
Revitalisation	'The state restoration, giving the opportunity to perform the utility function of this area'	Not used

In our estimation, the SER definition of ecological restoration is the most widely cited by the international community although there are frequent discussions on the need to give reference to social values (Davis and Slobodkin 2004; Winterhalder et al. 2004; Martin 2017; inter alia) or 'flexibility' in the face of a rising level of commitment to do large-scale restoration internationally (Higgs et al. 2018). The concept of ecological restoration as defined by the SER, or comparable definitions, has been adopted by global conservation and environmental groups including the International Union for the Conservation of Nature (Keenleyside et al. 2012), United Nations Convention on Biological Diversity (CBD 2016) and Conservation International (Martin 2017). It underpins the financing tools and partnership programs of international financial institutions such as the World Bank (www.worldbank.org).

Ecological restoration is increasingly being introduced into the lexicon of mining policy and regulation (e.g. Stevens and Dixon 2017; EPA 2009a, b). Its principles are utilised to guide and enhance restoration programs by land managers and industry leaders in significant mining regions such as Australia (e.g. Reddell et al. 1993; Koch 2007; Grant and Koch 2007; Standish et al. 2015; Wardell-Johnson et al. 2015; Stevens et al. 2016; Stevens and Dixon 2017), China (e.g. Li 2006; Ran et al. 2013; Lei et al. 2016), South America (e.g. Parrotta and Knowles 2001; Aronson et al. 2011; Balaguer et al. 2014) and Europe (e.g. Prach et al. 2013; Balaguer et al. 2014; Šebelíková et al. 2016).

The term 'rehabilitation' has been employed as a generic term for post-mining repair in the mining industry for many years and, as such, has some legitimacy. However, as Kaźmierczak et al. correctly identify, the term has now come to denote a return or rather *shift* to a desirable state that is not necessarily any prior pre-disturbance state, but rather merely the minimum 'repair' and 'replenishment' of one or more ecosystem service that legislation requires (e.g. Grigg et al. 2000). Recently, environmental considerations are becoming a key legislative requirement of mining projects in many developed countries (Mudd 2007; Stevens and Dixon 2017). Usage of the term 'rehabilitation' is now less favoured as a generic term, reflecting the shifts in aspirations of the mining industry to the goal of ecological restoration (Mchaina 2001; Bridge 2004; McDonald et al. 2016). Both the economic viability of the mining industry and its social and environmental licence to mine hinges upon an ability to sustainably and responsibly exploit mineral resources. Therefore, in cases where ecological restoration is to be the goal of post-mining repair (see, e.g. EPA 2009a, b), demonstrable capability in ecosystem recovery is necessary. Absence of such capacity not only jeopardises the sustainability of industry but places ecosystems, biodiversity and human communities at risk (Stevens and Dixon 2017).

Usage of the term 'reclamation' is also largely redundant in the recent international literature on ecological restoration and related activities, notably in the SER Primer on Ecological Restoration (SER 2004). Similarly, Clewell and Aronson (2013) have argued persuasively against using it in the ecological restoration lexicon. Reclamation was predominantly applied to the recovery of productivity to landscapes degraded by activities such as mining (e.g. Bradshaw and Chadwick 1980; Allen 1988), although the term has often been used where there is no regard to a pre-disturbance reference community (Prach and Tolvanen 2016). Therefore, the use of 'reclamation' to denote ecological restoration is erroneous (Clewell and Aronson 2013). Similarly, the term 'revitalisation' is primarily used in reference to socio-economic renewal in urban areas (Lasanta et al. 2006; Nelsen et al. 2010; Smith 2012) and thus clearly reflects a different enterprise than ecological restoration and rehabilitation.

Terminology needs to reflect process as well as outcome

The classification system presented by Kaźmierczak et al. (2017) offers six categories for a 'general way of reclamation' following mining (i.e. agricultural, forest, aquatic, natural, economic and cultural) and provides brief descriptions of the 'functions of the general way of reclamation', 'specific way of reclamation' and 'description of the way of reclamation' (see Table 7 in Kaźmierczak et al. 2017, p 7). This list represents a wide range of potential end land uses for an area of anthropogenically impacted land, but its excessive focus on final land use fundamentally misinterprets the challenge of ecosystem recovery.

Identifying appropriate endpoints in ecosystem recovery is of course essential. However, the most significant *constraint* to landscape recovery following mining disturbances is not which land use should exist following the cessation of mining activities, but degree of access to knowledge of the mechanistic processes by which ecological function can be returned to that land use. Ecological restoration is an activity or process, not a land-use type (Catterall et al. 2004). It involves the return of *functional* (the roles and processes that arise from living and non-living components of an ecosystem), *representative* (similarity to an appropriate real or notional benchmark native community) and *resilient* (capacity to recover following disturbances) ecosystems on post-mining landforms (consistent with McDonald et al. 2016). While the suite of land-use alternatives listed by Kaźmierczak et al. (2017) provides examples of how land might be managed following mining activities, highlighting the social context of ecological restoration (Martin 2017), it is of limited utility to end-users in guiding the planning,

process, or management of on-ground ecosystem recovery projects.

Terminology that reflects process as well as goals is likely to be most significant for industry end-users and environmental regulators. For these proponents, a lack of clarity around the terminology applied to recovery expectations might result in uncertainty not only in setting goals and objectives but also in predicting, driving and assessing recovery trajectories. The use of 'return of original state' or 'the state before' by Kaźmierczak et al. (2017), for example, does not reflect recent concepts of ecological restoration that recognise recovery itself as a process that enables a return of processes and the variability found in nature. As the targets and processes of recovery are adjusted as necessary to accommodate changed or predicted biotic or environmental conditions, ecological restoration does not attempt to immobilise an ecological community at some point in time (McDonald et al. 2016). Ecological restoration seeks to place an ecosystem on a trajectory of ecological recovery rather than impose a new direction or form upon it and aims to optimise the potential for local species and communities to recover and continue to reassemble, adapt and evolve (McDonald et al. 2016).

In terms of goals, Kaźmierczak et al. (2017, p 2) state that 'restoration allows no land-use flexibility and incurs the greatest cost'. In terms of the land-use flexibility, however, McDonald et al. (2016) recognises all 'highest and best' efforts at achieving substantial recovery of functional, representative and resilient ecosystems as ecological restoration even if they fall short of full recovery. Thus, ecological restoration can allow a range of utilitarian scenarios that are compatible with substantial degrees of ecosystem recovery.

Additionally, the statement by Kaźmierczak et al. (2017) that ecological restoration incurs the greatest cost is open to misinterpretation. Three approaches to ecological restoration can be identified, largely but not exclusively depending upon the scale and severity of disturbance. These include spontaneous regeneration by 'natural' regrowth and recolonisation, assisted regeneration by abiotic and biotic interventions to varying degrees of intensity and, lastly, full-scale ecosystem reconstruction (McDonald et al. 2016). Ecological restoration through natural recolonisation and assisted regeneration can be undertaken efficiently and economically (Miller et al. 2017), and studies suggest that recovery in at least some regions heavily impacted upon by mining operations can be effectively achieved by spontaneous regeneration (e.g. Prach et al. 2013; Prach and Tolvanen 2016). While full-scale ecosystem reconstruction on many heavily modified landscapes is likely to require significantly greater investment than this 'let-it-be' approach, solutions to increase the economic efficiency of ecological restoration have been examined in the recent scientific literature (e.g. Shoo et al. 2016; Iftekhar et al. 2017).

Arriving at international agreement on the definition and application of the terminology surrounding ecosystem repair is crucial. We commend the attempt by Kaźmierczak et al. (2017) to highlight this point. However, this agreement will only be reached through careful consideration of the terminology in common usage. It will allow regulators to develop unambiguous and achievable post-mining targets that align with the expectations of the community, improve the ability of industry to understand and meet these targets and facilitate analysis and improvement in recovery methodologies by the scientific community.

A lack of clarity in the use and application of terminology surrounding the recovery of post-mining areas may underrepresent high aspirations or could be misused to disguise low aspirations. Environmental repair efforts such as rehabilitation are suitable in situations where they represent the highest quality of recovery possible or are appropriate to the circumstances (McDonald et al. 2016), yet there is an increasing social expectation that 'full recovery', sensu McDonald et al. (2016), insofar as possible, be the preferred goal in many areas. No matter what the endpoint land use, however, scientific best practice must underpin the procedures which are put in place to ensure the desired outcome is achieved, and so we invite both industries and policy-makers to re-examine their terminology in the interests of attaining an internationally accepted lexicon.

Conclusions

We advocate a change from the generic use of 'rehabilitation' in the mining industry. We suggest that to provide clarity 'rehabilitation or ecological restoration' be used when a generic term is required, and either 'rehabilitation' or 'ecological restoration' be used when referring to the goals of a particular project.

Ecological restoration is recognised as one of the major strategies global society must pursue this century, as highlighted both in the scientific literature (e.g. Aronson and Alexander 2013) and by international agreements and fora such as the Rio Conventions (www.cbd.int/rio), the Bonn Challenge (www.bonnchallenge.org) and the United Nation's Forest and Landscape Restoration Mechanism (http://www.fao.org/in-action/forest-landscape-restoration-mechanism/en/). The utility and relevance of ecological restoration principles in improving the planning, targets, monitoring, efficacy and success of ecosystem recovery projects, particularly the cornerstone concept of a reference framework (Balaguer et al. 2014), is clearly reflected by the increasing appetite of the international community to embrace, test and apply this model (see, e.g. Aronson et al. 2017; Cross and Lambers 2017; Haapalehto et al. 2017; Nelson et al. 2017; Sluis et al. 2017).

Successful, effective and cost-efficient ecosystem recovery will most likely be achieved through three forward-looking paradigms: (1) targeted multidisciplinary research programs, (2) cross-disciplinary knowledge generation and transfer and (3) scientifically informed land management by industry guided by best-practice ecological theory (Suding 2011; McDonald et al. 2016; Aronson et al. 2017; Cross et al. 2017). In the face of large-scale global environmental challenges such as climate disruption, habitat fragmentation and the sixth extinction crisis, it is important to maintain high aspirations for the recovery of natural ecosystems following the rapid and sometimes disastrous environmental changes caused by mining (McDonald et al. 2016; Wardell-Johnson et al. 2016).

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