Making rewilding fit for policy

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Summary

1. Rewilding, here defined as *"the reorganization of biota and ecosystem processes to set an identified social-ecological system on a preferred trajectory, leading to the self-sustaining provision of ecosystem services with minimal ongoing management"*, is increasingly considered as an environmental management option with potential for enhancing both biodiversity and ecosystem services.
2. Despite the burgeoning interest in the concept, there are uncertainties and difficulties associated with the practical implementation of rewilding projects, while the evidence available for facilitating sound decision-making for rewilding initiatives remains elusive.
3. We identify five key research areas to inform the implementation of future rewilding initiatives: increased understanding of the links between actions and impacts; improved risk assessment processes, through e.g. better definition and quantification of ecological risks; improved predictions of spatio-temporal variation in potential economic costs and associated benefits; better identification and characterisation of the likely social impacts of a given rewilding project; and facilitated emergence of a comprehensive and practical framework for the monitoring and evaluation of rewilding projects.
4. Policy implications. Environmental legislation is commonly based on a 'compositionalist' paradigm itself predicated on the preservation of historical conditions characterised by the presence of particular species assemblages and habitat types. However, global environmental change is driving some ecosystems beyond their limits so that restoration to historical benchmarks or modern likely equivalents may no longer be an option. This means that the current environmental policy context could present barriers to the broad

implementation of rewilding projects. To progress the global rewilding agenda, a better appreciation of current policy opportunities and constraints is required. This, together with a clear definition of rewilding and a scientifically robust rationale for its local implementation, is a pre-requisite to engage governments in revising legislation where required to facilitate the operationalisation of rewilding.

Key-words: Ecosystem Processes; Ecosystem Services; Environmental Legislation; Monitoring and Evaluation; Restoration; Wildlife Management

Rewilding: a captivating, controversial, 21st century concept to address ecological degradation

During recent decades humans have dramatically hastened alterations to, and loss of, biodiversity worldwide (Millennium Ecosystem Assessment, 2005; Living Planet Report, 2014). As evidence mounts that extinctions are altering key processes important to the productivity and sustainability of Earth's ecosystems (Cardinale et al., 2012), environmental managers are faced with the pressing challenge of developing conservation actions that promote biodiversity retention and recovery to previously observed levels while supporting economic and societal development. At the same time, global environmental change is driving some ecosystems beyond their limits so that restoration to modern approximations of historical benchmarks is no longer an option; in such cases a new approach is needed to facilitate ecosystem services in novel ecosystems.

Among the remedial actions to the current biodiversity crisis under consideration, the concept of rewilding has emerged as a promising strategy to enhance biodiversity, ecological resilience, and ecosystem service delivery (see e.g. Lorimer et al., 2015; Pereira & Navarro, 2015; Svenning et al., 2016). Conservation scientists and policy makers are increasingly using and referring to the term rewilding (Jørgensen, 2015; Jepson, 2016; Figure 1), with rewilding being hailed as a potentially cost-effective solution to reinstate vegetation succession (Navarro & Pereira, 2015; Trees for Life, 2015); restore top-down trophic interactions (Naundrup & Svenning, 2015) and predation processes (Donazar et al., 2016; Svenning et al., 2016); and improve ecosystem services delivery through the introduction of ecosystem engineers (Cerqueira et al., 2015; Carver, 2016). The International Union for the Conservation of

Nature (IUCN) Commission on Ecosystem Management recently launched a task force on rewilding (IUCN, 2017) and several rewilding projects have now been implemented in multiple countries around the world (Figure 2). But rewilding has also attracted criticism from many scientists and from a wide range of stakeholders outside the scientific community, on legal, political, economic and cultural grounds (see e.g. Lorimer & Driessen, 2014; Arts, Fischer & van der Wal, 2016; Bulkens, Muzaini & Minca, 2016; Nogués-Bravo et al., 2016). Some rewilding proposals have been deemed rather alarming – even bizarre – by the general public (e.g. Bowman, 2012) and so the concept has yet to gain wide recognition as a scientifically supported option for environmental management.

Originally, the concept of rewilding was associated with the restoration of large, connected wilderness areas that support wide-ranging keystone species such as apex predators (Soulé & Noss, 1998). Since then, however, multiple definitions of rewilding have been proposed (Table 1), from which four broad forms have been distinguished (Table 2; Corlett, 2016a): Pleistocene rewilding (involving the restoration of ecological interactions lost during the Pleistocene megafauna extinction); trophic rewilding (involving introductions to restore top-down trophic interactions); ecological rewilding (allowing natural processes to regain dominance); and passive rewilding (primarily involving land abandonment and the removal of human interference;). Not only is there complexity in the different types of rewilding, but there is also confusion over the difference between rewilding and restoration. Restoration was originally understood as a management approach that aims to return ecosystems to the way they were, sometimes using continuous human interventions, while rewilding in its original concept aimed to return a managed area back to the wild in the form of a self-sustaining ecosystem, using minimal intervention, with an emphasis on processes rather than the end result (Corlett, 2016a). However, the distinction between the two concepts is no longer clear-cut. For example, “passive restoration” of forests is common in tropical landscapes (e.g. Melo et al., 2013) and the recently-coined term “open-ended restoration” refers to minimal intervention and the reduction or removal of human influence, as well as acceptance of future trajectories of ecological change (Hughes, Adams & Stroh, 2012). Altogether, the diversity of rewilding definitions and recent adaptations of restoration ecology, such as “renewal ecology” (Bowman et al., 2017), have resulted in a lack of clarity on what rewilding is, how it should be managed, and what it should achieve. While rewilding has already become an established concept, the lack of a formally agreed definition is, among other things, hampering efforts to advance its practice and incorporate it into policy.

As demonstrated by the impact of Monbiot’s (2013) book “Feral”, rewilding represents an opportunity to engage the wider public with the conservation agenda. In the face of the current biodiversity crisis there is, however, a pressing need to turn the rewilding concept into a proven approach for delivering environmental governance policy objectives, such as enhancing natural capital assets and the provision of ecosystem services. To achieve this potential, rewilding needs to be informed by the best science available; this can only happen if the research community broadly engages with rewilding, rather than relegating it to non-scientific arenas. To that end, we believe a definition that embraces the multi-faceted nature of rewilding is needed if it is to be more widely implemented and supported by public expenditure. Similarly, research priorities that enable the operationalisation of successful rewilding initiatives should be identified. Here, we address both needs, identifying some of the policy barriers that prevent rewilding from becoming an evidence-based option.

Embracing the multi-faceted nature of rewilding

We define rewilding as "*the reorganization of biota and ecosystem processes to set an identified social-ecological system on a preferred trajectory, leading to the self-sustaining provision of ecosystem services with minimal ongoing management".* Ecosystem processes are here understood as transfers of energy, material, or organisms among compartments in an ecosystem, following the definition introduced by Lovett et al. (2006). Examples of ecosystem processes thus include primary and secondary production, decomposition, heterotrophic respiration and evapotranspiration, which constitute the biological machinery that provides ecosystem services. Social-ecological systems are broadly defined as linked systems of people and nature, where humans are seen as part of, and not apart from, nature (Berkes & Folkes, 1998).

This new definition has multiple advantages over those previously suggested (Tables 1 & 2). First, it is not reliant on the concept of wilderness, a highly subjective notion that tends to promote the exclusion of humans from landscapes. There is, indeed, a vast diversity of perceptions of what the wild resembles and what natural means (Jørgensen, 2015). These perceptions vary geographically and culturally, and can be linked to people's access to nature (Carver, Evans & Fritz, 2002; Diemer, Held & Hofmeister, 2003; Bauer, Wallner & Hunziker, 2009). To date, the rewilding literature has generally referred to wilderness as areas where natural processes are permitted to operate without human interference (Lorimer et al., 2015). This reinforces the popular perception that the absence of sustained human intervention is central to the rewilding process (Corlett, 2016b). However, for three reasons, the notion that wild areas must be free of human influence is unnecessarily restrictive. First, one or more human species have been integral to most ecosystems in Africa and Asia for over 2 million years, and millennia for other continents. Second, experience accumulated during the development of the global protected area network indicates that any return to a "fortress conservation" approach is unlikely to work (West, Igoe & Brockington, 2006). Third, allowing people to interact with, and be part of, wild ecosystems should be compatible with facilitating the emergence of self-sustaining ecological units. Indeed, in most cases it would be impractical to suggest otherwise, as the ecosystems requiring restoration or rewilding are often on private lands or in regions where human activities are fully established (see e.g. Brancalion et al., 2013, 2016).

The second advantage of the proposed definition is that it encapsulates all forms of rewilding discussed so far, including trophic rewilding, Pleistocene rewilding, ecological rewilding and passive rewilding, as well as some activities that have previously been labelled as restoration (such as passive restoration or restoration reserves). Additionally, this definition allows for transitions into and through self-sustaining novel ecosystems as a possible trajectory for rewilding initiatives. This is important, as the 're' of rewilding has been previously understood as implying a return to some previous state, or historical benchmark, which might only be possible within specific spatial and temporal scales (Corlett, 2016b; Rohwer & Marris, 2016) and if there is agreement on the specific historical benchmarks to use (Epstein, López-Bao & Chapron, 2016; Trouwborst, Boitani & Linnell, 2017). Continual global change makes that goal unattainable in many situations (Marris, 2013). In this context, we agree with Corlett

(2016b) that a new vocabulary is needed so that the rewilding discussion can become relevant to both restoration and forward-looking approaches to enhancing the functional properties of ecologically-degraded landscapes under a changing climate (Kowarik, 2011; Lennon, 2015). This is why our definition refers to *reorganization*, with restoration to a previous state being a specific case of reorganization of the current state. In the context of rewilding, which is process-oriented, the components of an ecosystem's 'machinery' are, thus, reorganized in the way that damaged or lost operating parts are repaired, replaced, or retooled to resume smooth operation (service delivery) with low maintenance (wildness). This might involve replacing original parts (reintroductions), and if that option (restoration) is feasible, then it should be considered. But if original parts are not available, or if the operating conditions have changed substantially, then non-original parts (taxon substitutions) might be required to achieve the desired functional outcomes.

Defining a research agenda for rewilding

Recent reviews have concluded that the literature on rewilding remains heavily dominated by essays and opinion pieces, rather than empirical studies (Lorimer et al., 2015; Svenning et al., 2016). The existing emphasis on anecdotal evidence and subjective opinion makes it difficult to develop a scientific understanding of the risks and benefits of rewilding that is adequate to support evidence informed policymaking. In particular, there is a perceived lack of empirical information to support the emergence of a decision framework through which rewilding could be objectively selected as a preferred management approach. More ecological, quantitative, data-driven research may be required, although much could be achieved by adequately synthesising existing information. Without the formulation of a clear agenda that identifies what information and processes are needed to make rewilding useable in public and government policy, it is difficult to identify what data are missing, which studies are needed, and which frameworks need to be developed. Here, we identify five research areas where unorganised, incomplete or poor information is likely to hinder progress on rewilding. These are equally relevant to ecological restoration, which we regard as one approach to rewilding.

1. Target setting and implementation. The reorganisation of the biota and ecosystem processes can be achieved through a variety of management actions (such as reintroduction, eradication, outplanting/enrichment planting) used solely or in combination to set a system on a preferred trajectory. Although uncertainty about ecosystem trajectory characterises rewilding, rewilding projects are generally associated with clear targets, such as creating and maintaining a heterogeneous habitat mosaic, and promoting native vegetation (Table 3). There is yet little discussion on how these targets are set, how they relate to the identified preferred trajectory, and importantly, how to best choose the minimal course of management actions needed to reach the specified targets while maximising biodiversity outcomes. These discussions are particularly important when considering rewilding as an approach for the creation of novel ecosystems, where there is greater uncertainty over the trajectory of the ecosystem, and where there is no baseline information that can be used to guide management decisions. We argue that future rewilding project implementation plans should identify, from the onset, what the preferred trajectories, management targets and potential management actions are, providing a rationale for how these components fit together, so that adequate monitoring and evaluation plans can be drawn up early on.

In this respect, an improved understanding of the possible management actions for a given target, and the extent to which each may impact ecosystem processes, will support the production of more realistic and scientifically robust implementation plans.

2. *Risk assessment*. Rewilding is characterised by a high level of unpredictability in its ecological outcomes. This level of unpredictability is likely to vary with local conditions and the rewilding approach (or variant) considered (i.e., Pleistocene, passive, trophic, ecological), and may be particularly high when considering the introduction of new keystone species. Moreover, rewilding will occur in given socio-economic and political contexts: ineffective rewilding that is either very slow, or perceived to be less effective than alternative management approaches, could place projects and their ecological outcomes in jeopardy (Zahawi, Reid & Holl, 2014). Environmental management always operates in a realm where uncertainties dominate (Ludwig, Hilborn & Walters, 1993) but appropriate risk management can enhance the ability of policies to perform well despite scientific uncertainty (Schindler & Hilborn, 2015). Research is needed to facilitate the emergence of improved and pragmatic risk assessment processes, through e.g. the clear identification of ecological risks associated with each rewilding variant; the collection of information allowing the quantification of these risks according to local contexts; and the development of an agreed decision framework that could be used to identify, for a set of given conditions, which variant is associated with the lowest ecological risk. Understanding the time needed to deliver expected rewilding outcomes is also important for managing expectations; identifying how best to manage social and political risks associated with failing to deliver on these expectations is also key. Ultimately, being able to frame these risks as realistically as possible will allow appropriate mitigation measures to be put in place.

3. *Potential economic costs and associated benefits assessment*. All conservation policies operate within an economic context where value for money must be demonstrated. However, we still know very little about the ability of different conservation interventions, including rewilding, to deliver conservation benefits for a given cost (McCreless et al., 2013). This makes it very difficult to assess the relative expenditure to benefit ratio of a given approach against alternative interventions (Possingham et al., 2001). In the case of rewilding, the assessment of potential costs and benefits is particularly tricky, given the expected level of unpredictability in the outcomes. "Passive" options often have inherent and overlooked risks which may be more explicitly defined in active approaches, and the relative costs and benefits of each over time will depend on issues such as land tenure, opportunity costs and the need for long-term investments (Zahawi et al., 2014). Some form of economic assessment of rewilding is fundamental to cost-effective decision making since limited conservation resources must be spent wisely to deliver sustainable solutions and maximize conservation impact. To support decision-making and adaptive management, research is thus needed not only to assess our current ability to cost rewilding projects but also to improve our ability to predict spatio-temporal variation in future economic costs and associated benefits.

4. *Identification and characterisation of the likely social impacts*. It could be argued that one of the major handicaps to rewilding is the perceived negative impact of rewilding projects on local communities. The unpredictable outcomes that characterise rewilding approaches can make such approaches appear more risky than other conservation interventions, raising relatively high levels of concern over future impacts on nearby communities. If, for example, mitigation of direct impacts of humans on project success

entails reduced access to lands by local communities, then key stakeholders may become alienated. Some people living close to where rewilding initiatives are being implemented might suffer the costs of enhanced wildlife, in the form of crop and livestock depredation for example, while others may benefit from wildlife through ecotourism or associated ecosystem services. Hence, the costs and benefits of rewilding interventions are likely to be unevenly distributed across households, potentially exacerbating inequities or fundamentally changing the distribution of inequities within communities. A better understanding of the potential socio-economic impacts of rewilding, for each type of rewilding considered and in different socio-economic contexts, needs to be developed to be able to understand and mitigate against such unintended consequences. Arguably, many conservation interventions are still implemented without a clear identification and characterisation of the likely social impacts (Baylis et al., 2016) and so rewilding is currently associated with the same drawbacks characterising alternative options. At the same time, the few existing rewilding projects are mainly supported by private funding; state support for rewilding initiatives would help increase their scope and scale, and help mainstream the approach in environmental management. In that respect, robustly identifying the set of locations and associated rewilding variant suited to deliver the best societal outcomes would be particularly valuable to decide, at the national level, priorities for implementation. Such knowledge could help states decide to start investing in rewilding.

5. *Monitoring and evaluation*. Long-term, practical and scientifically sound monitoring and evaluation of rewilding projects are required to make sure the trajectory of change and targets remain desirable for the social-ecological system considered. This requires clarity on the preferred trajectories and targets for any rewilding project, as well as the

monitoring methods available for assessing outcomes across various spatial and temporal scales. Targets are likely to be centred on the functioning of ecosystem processes and delivery of services, including the facilitation of new processes and/or services as well as the enhanced functioning and delivery of existing processes and/or services. Given these constraints, monitoring and evaluation is more challenging for rewilding in general, where success is partially assessed by changes in processes and flows, than for circumscribed management interventions (such as restoration) that primarily target a particular state. Indeed, how to standardise the measurement of changes in ecosystem processes and service delivery is still open to debate (Geijzendorffer & Roche, 2013; Balvanera et al., 2016) and the practicalities are substantial. For example, carbon stocks in a forested system can be assessed in a cost-effective way in a single visit, but monitoring decomposition requires repeated measurements over years. Additionally, rewilding initiatives are all expected to benefit people, meaning that monitoring and evaluation processes should also assess the extent of societal benefit. Research on monitoring options for social impact (see e.g. Mascia et al., 2014) and ecosystem processes and services delivery (see e.g. Kupschus, Schratzberger & Righton, 2016) has grown substantially in the past decade, and these efforts could be used to support the identification of a relevant and practical framework for the monitoring and evaluation of rewilding projects. Satellite remote sensing, for example, offers promising avenues for the cost effective monitoring of ecosystem processes, functions and services, and could help inform such a framework (Cord et al., 2017; Pettorelli et al., 2017).

Integrating rewilding in the current policy context

Environmental legislation has a traditional focus on *in situ* conservation and the preservation of historical conditions, which have favoured the implementation of conservation projects aiming to restore previously observed benchmarks, facilitating data collection in these situations. However, global environmental change is also driving some species far beyond their traditional ranges and some ecosystems far beyond their limits: in such situations, restoring historical conditions may not be a realistic objective and the facilitation of the emergence of novel ecosystems may prove a more sensible and cost-effective alternative to address declining biodiversity and ecosystem services delivery (Hobbs, Higgs & Hall, 2013). To assess how best to support the emergence of novel ecosystems in various socio-economic and ecological contexts, experimentation and environmental manipulation may be required. Yet current policy drivers could present barriers to conducting these necessary large-scale, long-term ecological experiments. More broadly, revision of environmental policies and legislation that currently focus on existing or historical assemblages may be required for rewilding to fully reach its conservation potential (Hobbs, Higgs & Harris, 2009).

Two policy areas are particularly relevant to rewilding and may need specific attention: biodiversity policy, and agriculture and land-use policy. Here we use the European Union and US examples to illustrate how rewilding challenges existing environmental policy frameworks. In the EU, the current biodiversity policy is underpinned in legislation by the Birds Directive and Habitats Directive. These Directives are based on a 'compositionalist' paradigm, predicated on the preservation of particular species assemblages and habitat types (Jepson, 2016). Such an approach is codified in law in all Member States, with conservation policy driven by strong legislation that identifies targets for species and habitat protection. The protection of key communities, species and populations can, in many cases, be a legitimate target for an ecosystem services approach. However, rewilding projects focused on ecosystem processes and embracing uncertain outcomes could be difficult to accommodate within this policy framework, for example when protected area designations are predicated on the preservation of particular species or communities. Determining whether it is possible to systematically develop appropriate targets for rewilding initiatives that are compatible with existing commitments, and identifying options for adequate revisions of current legislations that do not risk undermining current levels of species and habitat protection are, thus, key challenges. The Common Agricultural Policy (CAP) is the other key piece of legislation relevant to rewilding discussions in the EU. CAP currently incentivises the maintenance of marginal lands in agricultural production through the structure of agricultural support payments, which can lead to inflated land costs and hamper large scale rewilding projects. Around 70% of payments under the CAP are conditional on land being in "good agricultural condition" and free of "ineligible features" such as naturally regenerating scrub (see e.g. Hart & Radley 2016), limiting opportunities for rewilding projects to be implemented. While "good agricultural condition" and "ineligible features" are a challenge for rewilding schemes in the EU, the CAP does not represent an insurmountable barrier to rewilding, with e.g. projects such as the Knepp estate having been made eligible under the Higher Level Stewardship scheme. But the current level of land use in the EU (with e.g. >70% of land being farmed in the UK) coupled with the CAP makes the implementation of rewilding projects more challenging.

In the U.S., federal government policy allows for the reintroduction of native species to national parks, as was successfully achieved for wolves (*Canis lupus*) in Yellowstone

(White & Garrott, 2013). However, rewilding projects on other public lands are limited by the potential for conflict with private ranchers holding grazing permits, who can hold strongly negative attitudes towards any wildlife species they perceive as predators of livestock or competitors for grazing resources. There is little prospect of integrating rewilding into the business models of public grazing permittees as long as the North American model of wildlife conservation, embodied in a bundle of policies that vary from state to state, precludes private individuals from deriving personal financial benefit from wildlife (Organ, Mahoney & Geist, 2010). Nevertheless, in the western U.S. where wild bison (*Bison bison*) share a public rangeland with cattle, some minor policy adjustments could compensate ranchers for wildlife-associated costs and allow the local community a share of the revenue from hunting permits, with positive implications for both the state and the social-ecological system (Ranglack & du Toit, 2016). If adopted, this could be a model for rewilding with bison on other public rangelands. In addition, there are several policy mechanisms emerging in particular states of the U.S. to incentivize conservation practices that could promote rewilding on private lands. These include state incentive programs to allow private landowners more flexibility in when and how hunting is conducted on their land, policies to reduce property-tax burdens on owners who maintain their land as wildlife habitat, and statutes that provide liability protection to landowners who allow recreational users on their land (Macaulay, 2016).

Conclusions

To progress the global rewilding agenda and support the emergence of large scale, publicly funded projects, a better appreciation of current policy opportunities and constraints is required. This, together with a clear definition of what rewilding is and a scientifically robust rationale as to how best to implement it given the local context, is a pre-requisite to engage governments in revising legislation where required to facilitate the operationalisation of rewilding. A re-thinking of the key pieces of legislation shaping biodiversity conservation and land-use in countries, such as the Birds and Habitats Directives in the EU, could facilitate the development and testing of novel environmental management funding mechanisms focused on payments for the delivery of desired ecosystem services, based on measurable outcomes rather than prescriptive management measures. Such novel approaches could provide an enabling environment for governments to support the piloting of well monitored and evaluated rewilding initiatives, which would contribute the evidence base required to demonstrate the effectiveness of rewilding initiatives in delivering ecological and socio-economic value.

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Table 1: Main broad definitions of rewilding, as proposed over the past five years.

Definition	**Key points**	**Reference**
"Rewilding has multiple meanings. These usually share a long-term aim of maintaining, or increasing, biodiversity, while reducing the impact of present and past human interventions through the restoration of species and ecological processes."	Focus on reducing impacts of management interventions Targets ecological processes and species restoration	Lorimer et al. (2015)
"Reintroduction of extirpated species or functional types of high ecological importance to restore self-managing functional, biodiverse ecosystems", "emphasises species reintroductions to restore ecological function"	Focus on (re)introductions Targets ecological functions	Naundrup & Svenning (2015)
"Rewilding implies returning a non-wild area back to the wild […]. This is the definition adopted in this review, except that I have followed normal usage in also including increases in relative wildness, i.e., from less wild to more wild."	Targets levels of wilderness	Corlett et al. (2016b)
"A process of (re)introducing or restoring wild organisms and/or ecological processes to ecosystems where such organisms and processes are either missing or are 'dysfunctional'"	Focus on (re)introductions Targets species composition and ecosystem processes	Prior & Brady (2017)
"The focus [of rewilding philosophy] is on benefits of renewed ecosystem function or processes (e.g. water storage, enhanced water quality, biodiversity support), rather than classic restoration thinking where a community converges towards a pre-defined target via a predictable trajectory"	Focus on non-predictable trajectory Targets ecosystem function/process	Law et al. (2017)
"The idea that unproductive and abandoned land can serve as new wilderness areas ('rewilding') i.e. self-sustaining ecosystems close to the 'natural' state often supported by (re-)introduction of large herbivores and habitat protection for carnivores and other species."	Focus on (re)introductions and habitat protection Targets self-sustaining ecosystems Supports low level of interaction between people and landscape	Van den Zanden et al. (2017)

Table 2: Type of rewilding, associated vision and aims, as well associated management interventions

Type of rewilding	Vision	Aim	Management interventions	Historical baseline	Scale
Pleistocene rewilding	Promotion of large, long-lived species over pest and weed assemblages; facilitation of the persistence and ecological effectiveness of megafauna (Donlan et al. 2006)	Restoration of ecological processes lost in the late Pleistocene	Translocations (including ecological replacements)	pre-human Pleistocene	Large scale
Trophic rewilding	Promotion of self-regulating biodiverse ecosystems (Svenning et al. 2016)	Restoration of top-down trophic interactions and associated trophic cascades	Translocations (including ecological replacements)	Not specified	Not specified
Ecological rewilding	Promotion of natural processes dominance (Corlett 2016b)	Restoration of ecological processes	Translocations (including ecological replacements)	Not specified	Not specified
Passive rewilding	Reduction of human control of landscapes (Navarro & Pereira, 2015)	Restoration of natural ecosystem processes	Little to no management, although intervention may be required in the early stages of the restoration process	Not specified	Not specified

Table 3: Examples of targets that may be considered by rewilding initiatives, and how these link to ecosystem processes and measurable outcomes

Target	Action	Ecological process(es) restored/enhanced	Ecosystem process(es) impacted	Measurable outcome(s)	References
Reduce over-grazing	Carnivore reintroduction	Predation	Primary and secondary production, evapotranspiration	Higher trophic complexity	Dobson (2014)
Creating and maintaining a heterogeneous habitat mosaic	Megaherbivore reintroduction	Herbivory	Primary production, evapotranspiration	Higher beta diversity	Vera (2009)
Reducing greenhouse gas emissions from permafrost soil	Megaherbivore reintroduction	Trampling	Primary production, decomposition, heterotrophic respiration, evapotranspiration	Reduced change in soil carbon stock	Zimov et al. (2005)
Promoting native vegetation	Megaherbivore reintroduction and/or herbivores exclusion/eradication, outplanting of native vegetation, removal of non-native species	Herbivory; seed dispersal	Primary production, decomposition, heterotrophic respiration, evapotranspiration	Native vegetation regeneration	Hansen et al. (2010), Sandom et al. (2013); Cid et al. (2014); Hodder (2014)
Restore self-regulating wetlands	Remove draining systems, reintroduce keystone species (beaver)	Water retention/flow Herbivory Habitat creation	Primary production, decomposition, heterotrophic respiration, evapotranspiration	Regeneration of hydrophilic/water tolerant vegetation; improved water quality; increased species richness	Wicken Fen Project (2017); Jones et al. (2009); Puttock et al. (2017)

Increase population viability	Corridor creation	Predation, competition, herbivory	Primary and secondary production, evapotranspiration	Higher genetic diversity within populations	Worboys & Pulsford, (2011)
Restore disturbance regime	Megaherbivore reintroduction	Herbivory, carbon sequestration	Primary production, decomposition, heterotrophic respiration, evapotranspiration	Change in fire dynamics (occurrence, severity)	Rewilding Europe (2017)

Figures

Figure 1: Number of articles listed in Web of Science that mention "rewilding" or "re-wilding". The search led to 77 papers, with the oldest articles from 1999.

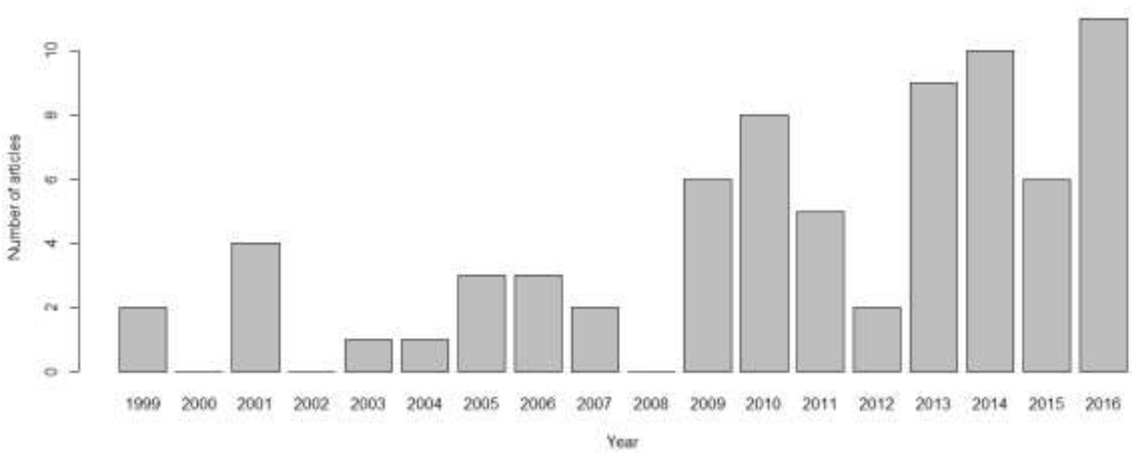
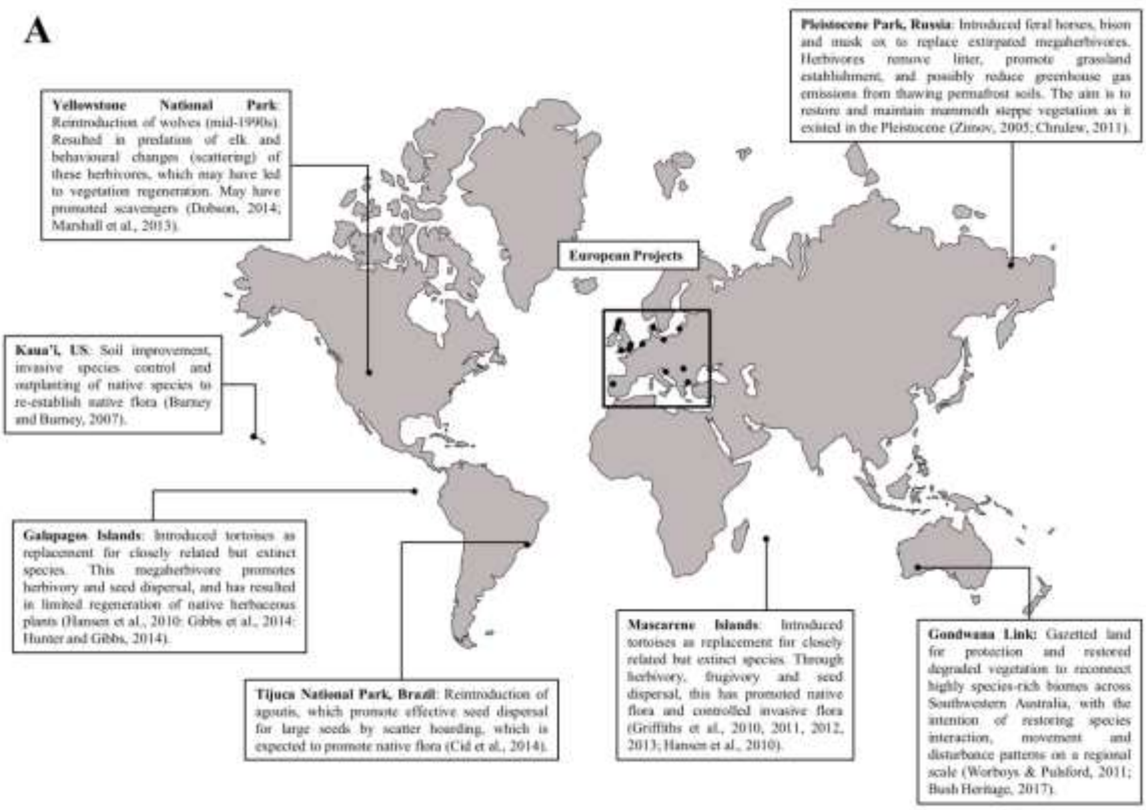
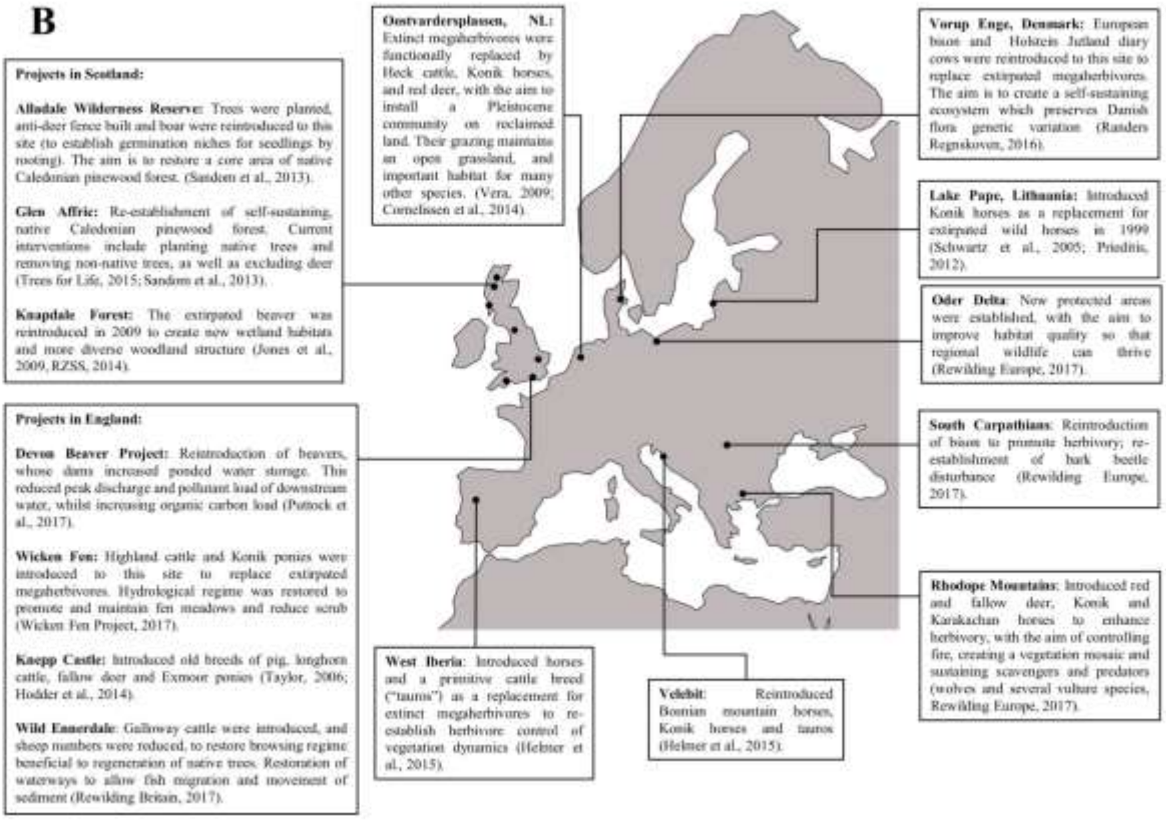


Figure 2: Examples of currently ongoing projects overtly labelled as “rewilding” (A) in the world and (B) in Europe.




B
Projects in Scotland:
Alladale Wilderness Reserve: Trees were planted, anti-deer fence built and boar were reintroduced to this site (to establish germination niches for seedlings by rooting). The aim is to restore a core area of native Caledonian pinewood forest. (Sandom et al., 2013).
Glen Affric: Re-establishment of self-sustaining, native Caledonian pinewood forest. Current interventions include planting native trees and removing non-native trees, as well as excluding deer (Trees for Life, 2015; Sandom et al., 2013).
Knapdale Forest: The extirpated beaver was reintroduced in 2009 to create new wetland habitats and more diverse woodland structure (Jones et al., 2009, RZSS, 2014).
Projects in England:
Devon Beaver Project: Reintroduction of beavers, whose dams increased ponded water storage. This reduced peak discharge and pollutant load of downstream water, whilst increasing organic carbon load (Puttock et al., 2017).
Wicken Fen: Highland cattle and Konik ponies were introduced to this site to replace extirpated megaherbivores. Hydrological regime was restored to promote and maintain fen meadows and reduce scrub (Wicken Fen Project, 2017).
Knepp Castle: Introduced old breeds of pig, longhorn cattle, fallow deer and Exmoor ponies (Taylor, 2006; Hodder et al., 2014).
Wild Ennerdale: Galloway cattle were introduced, and sheep numbers were reduced, to restore browsing regime beneficial to regeneration of native trees. Restoration of waterways to allow fish migration and movement of sediment (Rewilding Britain, 2017).
Oostvaardersplassen, NL: Extinct megaherbivores were functionally replaced by Heck cattle, Konik horses, and red deer, with the aim to install a Pleistocene community on reclaimed land. Their grazing maintains an open grassland, and important habitat for many other species. (Vera, 2009; Cornelissen et al., 2014).
Vorup Enge, Denmark: European bison and Holstein Jutland diary cows were reintroduced to this site to replace extirpated megaherbivores. The aim is to create a self-sustaining ecosystem which preserves Danish flora genetic variation (Randers Regnskoven, 2016).
Lake Pape, Lithuania: Introduced Konik horses as a replacement for extirpated wild horses in 1999 (Schwartz et al., 2005; Priednis, 2012).
Oder Delta: New protected areas were established, with the aim to improve habitat quality so that regional wildlife can thrive (Rewilding Europe, 2017).
South Carpathians: Reintroduction of bison to promote herbivory; re-establishment of bark beetle disturbance (Rewilding Europe, 2017).
Rhodope Mountains: Introduced red and fallow deer, Konik and Karakachan horses to enhance herbivory, with the aim of controlling fire, creating a vegetation mosaic and sustaining scavengers and predators (wolves and several vulture species, Rewilding Europe, 2017).
West Iberia: Introduced horses and a primitive cattle breed ("tauros") as a replacement for extinct megaherbivores to re-establish herbivore control of vegetation dynamics (Helmer et al., 2015).
Velebit: Reintroduced Bosnian mountain horses, Konik horses and tauros (Helmer et al., 2015).