Rewilding Knowledge Hub

Bibliography – Version 1.0

Photo: Peter Cairns, Wild Media Foundation

Lead Author: Dr. Chris Sandom

Research team: Dr. Chris Sandom, Dora Clouttick M.Sc., and Molly Manwill B.Sc.

Reviewed by: Dr. Joe Bull

Table of Contents

Sandom C.J., Clouttick, D., Manwill, M., Bull, J.W. 2016. Rewilding Knowledge Hub: Bibliography - Version 1.0. Produced by Wild Business Ltd for Rewilding Britain.

Executive Summary

Rewilding has been described as the optimistic agenda for halting the decline in biodiversity and restoring a balanced suite of ecosystem services. But, it is a field that currently lacks a comprehensive and dedicated evidence base, raising the question: will it work? The lack of an obvious and easily searchable body of supporting knowledge makes it difficult for policy-makers, practitioners and academics to consider the merits, risks, costs and opportunities of rewilding. Yet, the ideas behind rewilding are based on decades of ecological, physical and socio-economic research, as well as conservation experience. The Rewilding Knowledge Hub (RKH) Bibliography, presented here, is a first effort to begin to collate, structure, and disseminate this knowledge to a broad audience to help develop the science and practice of rewilding.

To reflect the ambition of covering the research relevant to rewilding, rather explicitly about rewilding, the RKH Bibliography is structured around six core themes: Rewilding, Geography, Ecological processes, Target species, Rewilding tools/methods, and Impacts. Using this structure we aim to provide a resource that allows users to:

1. Understand what is meant by rewilding;
2. Understand how different ecological processes function;
3. Link species to the delivery of ecological processes;
4. Select appropriate rewilding tools to restore ecosystems; and,
5. Understand and predict likely impacts of rewilding.

Initially we aim to work with students to develop the RKH Bibliography into a valuable educational resource that will help students develop and deliver rewilding based undergraduate and masters projects. We hope to inspire academic researchers to review the literature, identify knowledge gaps, and deliver new research to expand the science of rewilding. By summarising the knowledge held in the Bibliography we aim to help policy-makers and practitioners use this knowledge to develop effective rewilding strategies. Finally, we also hope this resource will allow anyone interested to explore the science behind rewilding to decide whether they think rewards are worth the risks.

This document describes Version 1.0 of the RKH Bibliography. The Bibliography has been created in the reference manager Mendeley. Mendeley is free to use, and offers a "social network" function allowing users to access and interact with the Bibliography. Anyone can access the Bibliography by signing up for a free Mendeley account and searching for and following the 'Rewilding Knowledge Hub' in Mendeley groups.

A small team of researchers at Wild Business Ltd has completed a preliminary, non-exhaustive, but broad sweep of literature relevant to rewilding. In total, 100 search terms were entered into Mendeley's search function, resulting in 9330 article hits. The researchers reviewed the title and abstract for each article to assess its relevance to rewilding and related topics. In addition to this academic literature search, grey literature from governmental and non-governmental organisations, and media articles have all been added to the Bibliography. In total, 2806 articles are currently stored in the Bibliography.

In order to make this literature more accessible it was structured using an array of 'tags'. Users of the Bibliography can select a tag of interest, which effectively sub-divides the Bibliography. Alternatively, the search function can be used to find articles. These methods can also be used in tandem. For example, selecting the tag 'Sturgeon' and searching for 'Reintroduction' reveals the 21 documents that discuss sturgeon reintroduction.

Rewilding has been defined as the mass restoration of ecosystems. To achieve this goal on a truly ambitious scale, rewilding must be on the agenda and minds of those passionate about nature and in a position to implement rewilding; this could include almost anybody. This Bibliography is to inspire, encourage and help anyone interested in rewilding to devise and implement effective rewilding strategies.

Glossary

Active Rewilding: the re-establishment of dysfunctional of ecological processes, typically achieved by returning species that provide ecological functions, or by removing human built structures such as drainage ditches.

Anthropocene: The era of geological time during which human activity is considered to be the dominant influence on the environment, climate, and ecology of the earth. The Anthropocene is most commonly taken to extend from the time of the Industrial Revolution to the present, but is sometimes considered to include much or all of the Holocene. (Oxford English Dictionary)

Assisted colonisation: is the translocation of species beyond their native range.

Back Breeding: is a structured breeding program to restore wild traits to domesticated species. The key example is an effort to create a breed of cattle with the traits of the extinct aurochs[1,2].

Biodiversity: short for biological diversity, is the "variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (Convention of Biological Diversity).

De-Extinction: also called resurrection biology**,** the process of resurrecting species that have died out, or gone extinct. (Encyclopedia Britannica)

Holocene: of, pertaining to, or designating the most recent geological epoch, which began approximately 10,000 years ago and still continues (others suggest the Holocene has ended and the Anthropocene has now begun) and which together with the Pleistocene epoch makes up the Quaternary period. (Oxford English Dictionary)

Managed Metapopulation: a group of populations connected by human management, typically by translocating animals between populations to over come dispersal barriers, such as fences.

Passive Rewilding: the release of ecological processes as a result of human ceasing to use, manage, or impact ecosystems. Often associated to or considered a by product farmers abandoning marginal land[3].

Pleistocene: Of, relating to, or designating the earliest epoch of the Quaternary period, between about 1,640,000 and 10,000 years ago, following the Pliocene and preceding the Holocene. The Pleistocene epoch was marked by great fluctuations in temperature, resulting in glacial and interglacial stages and corresponding falls and rises in sea level (the end of the final glacial stage marking the end of the epoch), and saw the appearance of the earliest forms of *Homo sapiens*. (Oxford English Dictionary)

Pleistocene Rewilding: is Active Rewilding using the Pleistocene as a inspirational n ecological baseline[4].

Rewilding: To return (land) to a wilder and more natural state. Used esp. with reference to the reintroduction of (large) mammals of or similar to species that were exterminated locally at some earlier period. (Oxford English Dictionary)

Succession: The sequence of ecological changes in which one group of plant or animal species is replaced by another. (Oxford English Dictionary)

Taxon Substitution: Replacement of extinct species with closely related species that have similar roles within an ecosystem[5].

Trophic Cascade: "in ecological communities – trophic cascades – are defined as the propagation of indirect effects between nonadjacent trophic levels in a food chain or food web. Typically, cascades are driven by predation from the top-down, with altered herbivore densities mediating the ultimate effects on the biomass of primary producers." (Encyclopedia of Life Sciences)

Trophic Rewilding: "is an ecological restoration strategy that uses species introductions to restore top-down trophic interactions and associated trophic cascades to promote self-regulating biodiverse ecosystems." [6]

1. Introduction

1.1. Conservation management is failing to stem the tide of biodiversity loss. In Britain, the 'State of Nature' report[7] highlighted that 60% of species studied have declined over the last 50 years. Further, the National Ecosystem Assessment highlighted that 30% of ecosystem services – the benefits and services nature provides society and the economy, such as clean water and flood alleviation – are in decline, and many others are impoverished compared to historical baselines[8].

1.2. In light of this, many feel there is an urgent need for innovation that produces new solutions to meet this challenge. Rewilding, an ecological process restoration approach to conservation that seeks to re-establish functioning ecosystems, has been suggested as such an innovative approach[3,6,9,10]. There is increasing interest in determining the feasibility, value, risks and costs of employing rewilding more widely in Britain. For example, rewilding has been the focus of current research[11]; has been highlighted as a possible management approach in mountain, moorland and heath habitats in the follow-up to the first National Ecosystem Assessment[12]; and, has been discussed as a potential solution to help mitigate flooding[13].

1.3. Others have raised concerns about rewilding. For example, some suggest that it presents considerable risks, that priority should be given to extant species rather than reintroducing lost species, that there is limited scientific support for rewilding, and that considerable caution should be employed when putting rewilding into practice because of the unknowns of altering ecosystem dyanmics[14–19].

1.4. As a young discipline, rewilding lacks a well-developed, dedicated, and empirical literature. This means that there are limited easily-searchable resources for researchers, policy-makers and practitioners to draw upon when considering the merits, risks, opportunities, and costs of rewilding[6]. Here we present a collation of literature relevant to rewilding from academic, grey and media sources. This is a first attempt to draw upon the breadth of knowledge, across the wide range of relevant disciplines, to create a knowledge base for those seeking to test, implement, research and improve rewilding. This resource is called the Rewilding Knowledge Hub (RKH) Bibliography.

1.5. The purpose of the RKH Bibliography is to collate, structure and disseminate research to a broad audience of students, researchers, practitioners, and policy-makers, as well as interested members of the public. It is an effort to present the raw research to as wide an audience as possible to allow anyone to make up their minds about rewilding.

1.6. The Bibliography is designed to encourage a two-way transfer of knowledge between the hosts, Rewilding Britain, and the users of the Bibliography. The literature it lists represents the outcomes of an initial knowledge gathering effort. We encourage those using the Bibliography to list additional relevant articles, and highlight their own ground-breaking findings.

1.7. The Bibliography is targeted at students, academics, practitioners, and policy-makers. For students, we hope to engage them to develop the RKH so that it provides a valuable educational resource and provides inspiration for undergraduate and masters research projects. For academics, we hope they will use and develop this resource to identify knowledge gaps, conduct the research to fill these gaps, and share their findings with the RKH. Finally, for policy-makers and practitioners we hope the research and perspectives presented in the RKH will be summarised and disseminated to help improve the implementation of ecological process restoration.

1.8. This report presents the rational for creating the bibliography, details of the method used to create it, gaps in the search effort that need addressing, a summary of the database, and a selection of questions that we feel could be addressed as undergraduate or masters projects.

1.9. The Bibliography and this report focuses on six key theme of rewilding: 1) Rewilding itself, 2) the geographical variations in rewilding ideas, 3) Ecological processes that rewilding could help restore, 4) Species that Rewilding Britain have proposed for reintroduction, 5) the tools and approaches to apply rewilding, and 6) the impacts rewilding might have.

1.10. The report contains research from across the world, but the focus is on rewilding in Britain.

2. Methodology

2.1. Selecting a reference manager

2.1.1. The Bibliography has been created in the open access reference manager, Mendeley (www.mendeley.com). Mendeley was selected as it is free to join and use, and because it offers an "academic social network", meaning the bibliography is accessible to anyone with an internet connection.

2.1.2. A Mendeley 'group' named the 'Rewilding Knowledge Hub' has been created and all references are stored within this group. Those interested in accessing the RKH Bibliography can sign-up to follow this group by creating a Mendeley account and searching and following 'Rewilding Knowledge Hub' in Mendeley Groups. Followers get access to the bibliography, notification of updates, and the ability to add and tag literature they feel is relevant to rewilding.

2.1.3. Mendeley also offers a tagging function that allows articles to be assigned to key words or phrases. This function allows the bibliography to be organised, helping users navigate the literature in a structured way.

2.2. Establishing a tagging structure

2.2.1. The tagging structure was devised to group articles by their relevance to key themes. Figure 1, describes the tagging structure of the bibliography. Key themes are presented in green ovals, such as 'Ecological Processes'. Surrounding these themes are the tag names under which articles have been assigned. For example, the tags associated to rewilding include 'Pleistocene', which are articles relevant to rewilding that use the Pleistocene epoch as a baseline.

2.2.2. The links drawn between themes in Figure 1 are simply a description of how the research team think different themes link together in their relevance to rewilding. We have proposed a loose hierarchy (Themes are in bold, and tags in single quotation marks; Rewilding is both a theme, because rewilding is multifaceted and so requires sub-headings, and a tag, because it is interesting to consider articles that consider rewilding specifically). So, for example, '**Rewilding'** is the restoration of **Ecological processes**, such as 'Predation', 'Herbivory' and 'Dispersal', these processes can be restored by re-establishing **Species**, such as 'Wolf', 'Bison', and 'Beaver', which in turn can be achieved through **Rewilding tools** such as 'Reintroduction', 'Taxon substitution', or 'De-extinction'.

2.3. Populating the Rewilding Knowledge Hub Bibliography

2.3.1. The researchers generated a set of search terms, with input from three reviewers (Appendix A). These consisted of 'Rewilding', nine key ecological processes, the 21 species that have been proposed for reintroduction by Rewilding Britain, and 19 sites that are associated with rewilding. Rewilding, and 16 of the rewilding sites were searched without secondary search terms. The remaining search terms were paired with secondary terms, and in some cases tertiary terms, to target search effort on the most relevant articles. Secondary search terms for ecological processes and species consisted of 'restoration' or 'reintroduction' respectively, and a series of ecosystem services or disservices. Tertiary search terms were mostly geographic regions.

2.3.2. In total, 100 search terms were used, generating approximately 9000 articles that were considered for inclusion. Other search terms are also relevant and we have proposed further search terms in Appendix A.

2.3.3. Each search term, using the link 'AND' where secondary or tertiary terms were included, was entered into the Mendeley online search tool. The citations generated were assessed according to their title and abstract for their relevance to rewilding and the themes of rewilding. If an article was deemed relevant, i.e. it conformed to the search term as it was intended, it was added to the RKH Bibliography.

2.3.4. Mendeley offered a useful but limited source of literature for this first collation effort. Google Scholar and the Web of Science are more comprehensive and future efforts to collate relevant literature should use these sources as well.

2.3.5. Each of the articles added was tagged according to its relevance to the tag, as described in Appendix B. Articles were assigned as many tags as were relevant. Article tags were reviewed by searching for key terms within the RKH Bibliography and adding relevant tags that had not been included on the first pass.

2.3.6. The bibliography is not exhaustive nor is there an even level of effort to identify relevant articles for different tags. The purpose of this report is to provide an introduction to the knowledge available, which will be built on over time by working with students and researchers.

2.4. Accessing the literature

2.4.1. Where possible, the title, authors, journal, abstract and url are given for each article. This information is incomplete for some articles. There are also inaccuracies with the Mendeley records meaning there are also inaccuracies in the RKH Bibliography.

2.4.2. Copyright prevents the full text of articles being made freely available to users of the RKH. Those with access to journals through libraries and academic institutions will be able to access articles through their usual channels.

2.4.3. Many articles are now beyond their embargo period and are freely available online and can be searched for online for those that do not have direct access to journals.

2.4.4. Summaries of key research will be published periodically and made available online. These summaries will be targeted to those who are less likely to have direct access to journals.

2.5. Attracting users

2.5.1. The Bibliography will be described on various websites with instructions on how to access and follow the RKH Mendeley group. This document and further summaries will also be made available on those websites.

2.5.2. The Bibliography will be publicised on social media to attract users and contributors.

2.5.3. The Bibliography will also become a key resource for the University of Sussex's Rewilding and Ecosystem Services module, of the Global Biodiversity Conservation MSc.

2.6. Future development

2.6.1. We encourage those who wish to use the RKH Bibliography to contribute to this resource by adding and tagging relevant articles.

2.6.2. In time we hope the RKH Bibliography will facilitate a systematic review of these topics.

2.6.3. We ask that users do not delete articles. If you think article has no relevance to Rewilding please flag it to the administrator, Chris Sandom.

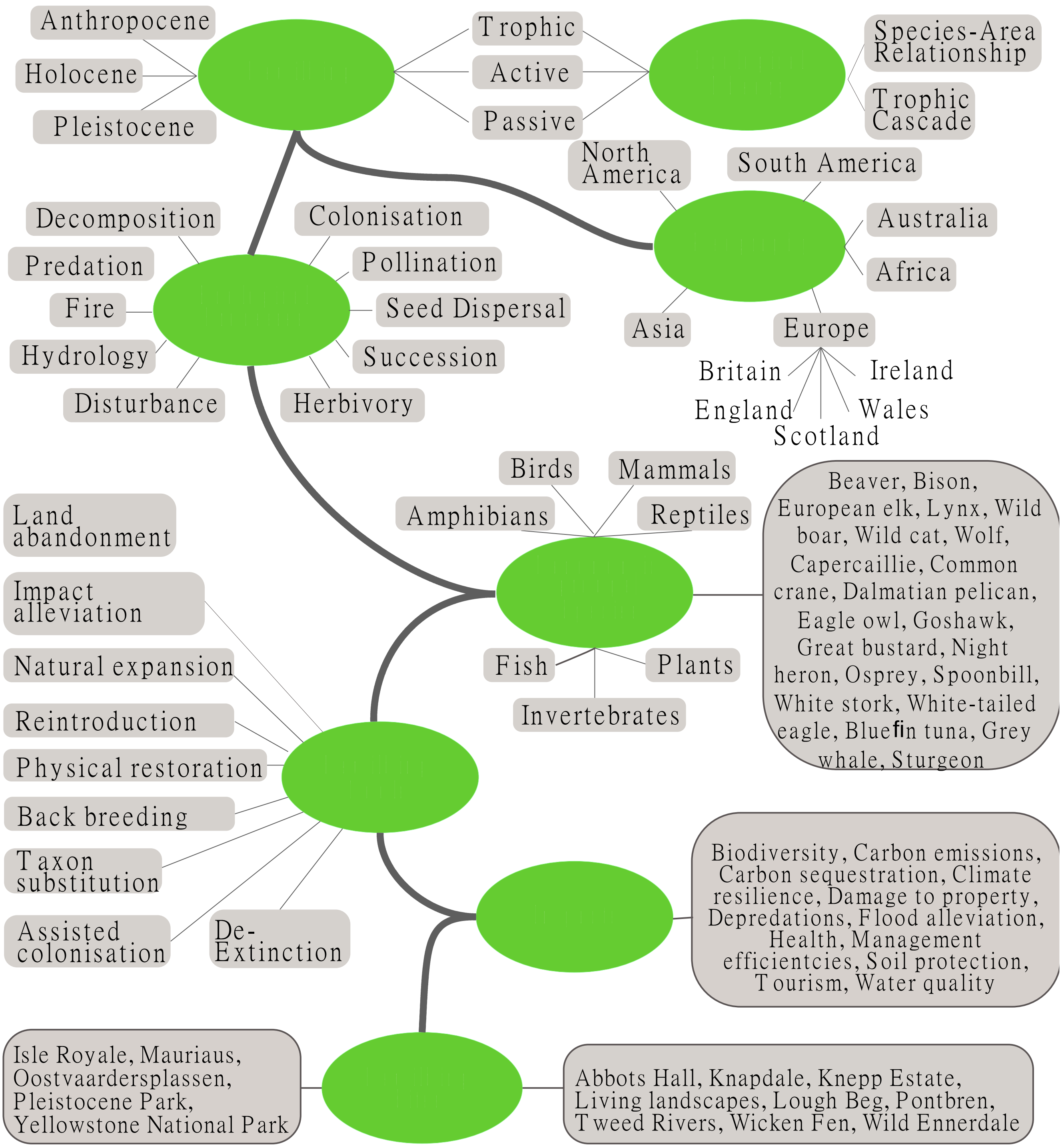

Fig. 1: A diagram describing how the research team think different themes link together in their relevance to rewilding.

3. The Rewilding Knowledge Hub Bibliography

This section draws attention to the current content of the Bibliography. It is a cursory introduction, sub-sectioned by the 6 core key themes of rewilding: Rewilding, Geography, Ecological Processes, Species, Rewilding Tools, and Impacts.

This summary does not represent in an in depth review of all the articles stored in the Bibliography. Instead, it seeks to highlight examples the type of content available in the Bibliography, particularly articles relevant to the rewilding of Britain.

3.1. Rewilding

In total, 141 articles refer explicitly to 'rewilding', 're-wilding', or 'rewilders'. The earliest article using the term is by Soulé and Noss in 1998[9]. The 141 articles encompass a range of rewilding definitions. Recent reviews suggest the meaning of rewilding varies according to the ecological baseline used for ecosystem function, and the approach by which rewilding could be implemented[3,6].

3.1.1. ***Baselines***: Three baselines have been established for rewilding: the Pleistocene, the Holocene and the Anthropocene[3]. These baselines describe ecosystem function under different degrees of human impact, and are typically used to identify which species should be considered for reintroduction and what densities these species should occur at. These baselines are not necessarily mutually exclusive.

3.1.1.1. The term '**Pleistocene** Rewilding' was coined by Donlan et al. in 2005[20]. In establishing the term, the authors made the case for using the Pleistocene epoch (a period in time between ~2.6 million to 11,000 years before present) as the baseline for rewilding. Their argument is based on an ecological and evolutionary perspective that, unlike more recent times, the Pleistocene includes a vast ecological history not impacted by modern humans outside of Africa[21]. With the introduction of this more controversial form of rewilding, Donlan et al. increased the attention given to rewilding[17,18,22–28]. A particularly key and controversial part of the Pleistocene Rewilding proposal was the suggestion that extinct species could be replaced by extant close relatives. This idea has given birth to a new conservation tool called '**Taxon Substitution**'[5]. The introduction of this type of conservation translocation has since required the IUCN to expand their Conservation Translocation guidelines[29].

3.1.1.2. The '**Holocene**' baseline is the more typical and less controversial baseline used for rewilding. The Holocene stretches back from historical times to the end of the Last Glacial (~11,000 years ago). Particular focus is given to the period prior to the expansion of agriculture[30]. The Holocene baseline is typically seen to have more climatic continuity to the present, compared to the relatively distant interglacials of the Pleistocene. Further, species naturally present in the Holocene are generally considered 'native' to a region and more realistic candidates for reintroduction[26]. The almost ubiquitous presence of modern humans during the Holocene makes it more relevant to the challenges of conservation in a human dominated world. Although, by the same token, the ecology of the Holocene must also be viewed in the context of the impact of human hunter-gatherers. Relatively few articles in the Bibliography explicitly refer to the 'Holocene' (18), however, at least another 47 consider a historical perspective, situated in the Holocene.

3.1.1.3. The **Anthropocene** is a baseline in a slightly different sense[3]. Rather than being a historic baseline to learn from, it is the current baseline. The Anthropocene baseline, thus, by contrast, ensures rewilders consider the future as well as the past. Any rewilding must be achieved in the context of what is possible today[6,31,32]. Thus, authors typically use Pleistocene and Holocene baselines as a point in the past to guide future restoration of ecological processes, but use the Anthropocene as a baseline for the unusual human-impacted ecology operating today. Interestingly, in the Anthropocene, humans should be seen as a driver of speciation as well as extinction[33].

3.1.2. ***Rewilding approaches***: Three broad, non-exclusive approaches to rewilding have become apparent: 'Passive', 'Active', and 'Trophic' (Trophic can be considered a subdivision of Active). These three ideas draw on different areas of ecological theory to support their approach.

3.1.2.1. Passive rewilding

Passive rewilding is the reassertion of ecological processes in response to a lessening of human impacts. For example, passive rewilding spontaneously emerges from agricultural land abandonment[3,34]. This approach is a simple reduction in human interventions in the functioning of ecosystems, and is not preceded by active restoration. It is particularly well suited to large areas that are largely ecologically intact with the opportunity for missing species to re-colonise naturally[35]. Large and well connected areas are important because the 'Species-Area' relationship, highlights that larger, more joined up areas support more species[9]. It should be noted that agricultural land abandonment leads to passive rewilding, but land abandonment is not a requirement of rewilding. The relationship between humans and wilderness has been a focus of discussion [36].

3.1.2.2. Active rewilding

Active rewilding is an approach that includes 'trophic rewilding', described below, but includes the restoration of processes such as hydrology and fire that are not driven by species reintroduction. Active rewilding promotes a front loading of ecosystem interventions to restore ecosystems to more functional states, followed by passive rewilding with limited or no human intervention[10].

3.1.2.3. Trophic rewilding

Trophic rewilding 'is an ecological restoration strategy that uses species introductions to restore top-down trophic interactions and associated trophic cascades to promote self-regulating biodiverse ecosystems.'[6] Trophic rewilding is operationalizing the trophic cascade theory, which is now widely described[37–39], but has not been broadly used as conservation tool[6].

3.2. Geography

Rewilding is a multifaceted concept. Part of this variation in meaning comes with geography. Here we briefly explore how rewilding varies across the world.

3.2.1. Global

The rewilding literature stored in the Bibliography focuses on Europe (57) and North America (38), while South America (4) Australia (3), and Asia (3) feature less frequently, although this might be related to the search being conducted in English. The concepts of Rewilding and Pleistocene Rewilding were both born in North America[9,20]. Further, the wolf reintroduction Yellowstone National Park and the associated trophic cascade remains the key example of rewilding[3,6], although, it should be noted that the word rewilding is not typically used in articles about the wolves of Yellowstone[37]. The idea of rewilding has generated most traction in Europe, perhaps because of the relative lack of wild land compared to North America[40].

3.2.2. Britain

Visions for Rewilding have been set out for Britain[11] in general, but also specifically in Scotland[41], and Ireland[30]. For Britain, one article describes rewilding as a radical leap forward in our efforts to conserve nature in Britain[11]. For Scotland, the article reviews rewilding and highlights its relevance to Scotland[41]. It is the view of the author[41] that rewilding has the potential to benefit Scotland's environment, society and economy. The article considering rewilding Ireland rules out Pleistocene rewilding, but indicates restoring a predator rich and herbivore poor mammal community to Ireland as a unique ecosystem in Europe is an exciting opportunity[30].

3.3. Ecological processes

Restoring ecological and geomorphological processes is the consistent theme that runs through the multiple definitions of rewilding. Ecological processes can be described to operate in two directions within a food-web: 'bottom-up' and 'top-down'. Bottom-up processes are interactions between species that start at the base of the food web, the plants, and work up, influencing the populations and communities of herbivores and predators. The concept of succession, the progression from one community of species to another, typically as a result of early communities 'preparing the ground' for latter communities that are normally better competitors, is key[42]. Top-down processes start at or near the top of the food-web, predators and herbivores, and work down[43]. Top-down processes are typically referred to as 'Trophic Cascades'. If bottom-up succession dominates, it is thought a collection of climax communities will form, which are often wooded, depending on climate and soil conditions[44]. Adding top-down processes, along with additional processes such as fire and hydrology, is thought to create spatially dynamic interruptions to succession. Together, these processes, along with others, are thought to create a spatially and temporally diverse mosaic of ecological conditions, which will provide for biodiversity[45,46].

Traditional restoration ecology has typically focused on the restoration of plant communities, often with the aim of restoring habitat for species higher up the food-web. Rewilding has promoted a greater focus on top-down processes, by highlighting the importance of the impact of predators and herbivores on vegetation communities[6,9]. Here we briefly consider some of the literature within the RKH Bibliography that describes the function, and restoration of a selection of key processes.

3.3.1. **Top-down trophic interactions**:

3.3.1.1. **Predation**

In total, 563 articles in the RKH Bibliography consider the function or the restoration of predation. Of these, 209 discuss predation by wolves, and 76 mention the wolves of Yellowstone National Park (YNP). This highlights the extent of the interest the reintroduction of wolves to YNP has generated as an example of restoring predation[47]. Lynx are considered in 39 articles, most (26) of these articles address predation of livestock (depredations), but some consider the ecological role of predation on wild prey species[48]. More broadly, two articles discuss how the process of predation has been altered globally as a result of the dramatic decline in large carnivores[43,49].

The ecosystem consequences of predation, or the trophic cascade, are considered in 171 articles in the Bibliography. Trophic cascades are reported to emerge in a number of different forms, including the consequences of predators: reducing prey abundance[47,50–52], altering prey behaviour[49,53,54], and by reducing the abundance of competing smaller (or meso) predators[55–57]. The impact of human actions on predator-prey interactions are also considered[58]. An important aspect of how predation functions is the degree to which predation is compensatory (kill animals that would die soon anyway) or additive (kill healthy animals with the potential to reproduce)[59]. Where predation is compensatory, predator reintroduction is not anticipated to trigger a trophic cascade.

3.3.1.2. **Herbivory** (Grazing and Browsing)

In total, 480 articles in the RKH Bibliography are tagged herbivory. There is considerable overlap between predation and herbivory, with 185 articles tagged with both. This highlights the typical trophic cascade pathway from predators to herbivores to plants. However, research on a recovering African wild dog population indicated that while the return of this predator reduced the abundance of its primary prey, the herbivorous dik-dik, this did not change the browsing pressure and so did not trigger a trophic cascade[60]. Indicating that trophic cascades cannot be assumed from the return of a predator and subsequent decline in prey.

There is considerable research stored in the Bibliography considering the proper functioning of herbivory. These papers are essentially addressing the question: when are ecosystems over- or under-grazed? Research includes using the past to assess the abundance and impacts of herbivores using fungal spores[61], beetles[46] and pollen[44,62]. Dr. Frans Vera proposed that the natural condition for Holocene Europe is a heavily grazed and primarily wood-pasture system[62]. This has been a major challenge to the more traditional view that Europe was dominated by closed forest[44]. Regardless of the baseline, it seems clear that European species require a mosaic of vegetation communities, varying from open to closed[45]. What is less clear, is understanding which assemblage of herbivores and predators deliver this mosaic – in particular, are mega-herbivores needed[46]?

Elsewhere, research at Gorongosa National Park, Mozambique, following the collapse of large herbivore populations as a result of the civil war, has described how the ecosystem responded with a 30% expansion of woodland. The current and on going re-establishment of herbivore populations will indicate if restoring the herbivore community will reverse this trend[63]. Sergey Zimov, founder of the Pleistocene Park, proposes that the restoration of grazers can restore the grass dominated ecosystem known as the mammoth steppe[64], however, the existence of mammoth steppe has been questioned [65]. Equally controversially, taxon substitution has been used on Mauritius to replace the herbivory of an extinct giant tortoise to reportedly positive effect[66].

Other articles have considered the finer dynamics of herbivory, considering how herbivores influence species composition of vegetation communities[67], how specific species are impacted by different grazing regimes[68], how, in this case the beaver, can impact urban vegetation communities[69], as well as providing descriptions of the diet of particular herbivores, such as common cranes[70]. More broadly, a review of the global impacts of the world's largest herbivores, and the perilous state many of these species are in is discussed by Ripple et al.[71]. A Natural England report actively discusses the reintroduction of 'natural grazing'[72].

The articles stored in the RKH Bibliography suggest it is difficult to know which community of predators and herbivores will create a rich mosaic of habitats that provides for all dependent species.

3.3.2. **Bottom-up processes**

3.3.2.1. **Seed dispersal/Colonisation**

There are 57 articles in the Bibliography tagged 'Seed dispersal'. Succession is dependent on the arrival of new species to colonise the community. For species to arrive, they must have a means of dispersal from one site to another. This is true of both plants and animals, but while animals can typically move themselves, plants must rely on other agents.

Wind, water and animal vectors disperse plant seeds. Here we focus on animal vectors. Humans, by contributing to the Pleistocene megafauna extinction, have long suppressed the dispersal of the largest seeds that were adapted to be dispersed by the largest animals[73]. The remaining large mammals still play an important role in seed dispersal. Research from Bialowieza National Park, Poland, has highlighted the importance of having a complete guild of large herbivores to ensure the widest variety of seeds are dispersed effectively[74].

The behaviour of seed dispersers is also important. For example, research has demonstrated the movement patterns of seed-dispersers such as birds can be important in influencing whether tree seeds are dispersed to deforested areas. Woodland birds were more likely to overcome their reluctance to leave wooded areas when lone trees in pastures are heavy with fruit[75]. This should encourage establishing lone fruiting trees in landscapes.

A database recording the plant species that animals disperse would be a useful tool for promoting the restoration of seed dispersal processes. Databases that record the diet of all mammals and birds are available and could be refined to provide an assessment of their capacity to disperse seeds.

3.3.2.2. Tree regeneration

Within the RKH Bibliography 292 articles are tagged 'Tree regeneration'. In Europe, woodland is typically seen as the climax vegetation community under most environmental circumstances, except where strong top-down herbivory prevents this[44,46,62]. However, this issue is fiercely debated [62,76]. However, the limited native woodland cover in Britain, particularly in the North, is of conservation concern, for example, most of the species that have been recorded to go extinct in Britain are associated with woodland habitats[77].

Arguments have been made for restoring woodland or allowing trees to re-establish themselves. For example, Trees for Life, a restoration project in the Scottish Highlands that is often linked to rewilding, has planted over 1 million trees in an effort to restore what is known as the Caledonian Pine Forest[78]. However, other than where trees are planted to restore a lost seed-source, in the context of rewilding definitions, planting woodland seems more associated to ecological restoration rather than rewilding.

It would be anticipated that, at least in some places, succession would restore regions of woodland in Britain if ceased land management. However, there is also evidence to suggest an abundant large herbivore community is suppressing tree regeneration, at least in the north[79]. Other factors such as seed source, and limited germination niches in established ground vegetation communities also limit tree regeneration[79].

Elsewhere, concepts of succession have been applied to woodland restoration on reclaimed coal wastes using nurse shrubs to prepare the ground to allow tree establishment[80]. Other research has explored emulating the effect of nurse plants to allow tree regeneration[81]. Research from Yellowstone NP has highlighted that while wolf reintroduction might have reduced browsing pressure, hydrological processes also need to be restored to allow tree regeneration[82].

3.3.3. **Disturbance**

3.3.3.1. Rooting

In total, 35 articles discuss the process or impact of wild boar or pig rooting behaviour. Rooting is a foraging behaviour allowing these animals to access roots, tubers, and animals living beneath the vegetation and soil. Rooting by Suidae (the pig family) breaks up vegetation, exposing bare ground beneath, creating new germination niches. The rate at which wild boar root was recorded to be in the 10s of m^2 per boar per week in the Scottish Highlands[83]. Wild boar and feral pigs are reported to prefer rooting in soil with high moisture content[84]. Wild boar have been reported to consume over 400 different species[85].

Wild boar research has been targeted where wild boar are an invasive species, focusing on the impact rooting has on native plant communities and human landuses[86]. Many of the articles discussing wild boar refer to the 'damage' done by rooting, regardless of whether they are discussing the impact of boar to wild vegetation communities or human resources, suggesting rooting behaviour is seen as a negative impact. More accurately, rooting is typically seen as damaging when it interacts with human land uses such as agriculture or golf courses[87]. Wild boar can also reduce bluebell cover in culturally significant bluebell woods in Britain, at least in the short term[88].

3.3.3.2. Fire

Fire is discussed in 75 articles stored in the RKH Bibliography. Research from the Pleistocene reports that fire, humans, and herbivores can interact to change the nature of continental ecosystems[89,90]. The natural interaction between herbivory and fire can create a mosaic of vegetation structures, which has been suggested as important form of rewilding[91,92]. Importantly, herbivores can reduce the fuel load within vegetation communities, reducing the likelihood of fire. Herbivores can also be attracted to areas of recent fire to feed on recovering vegetation keeping them open.

Fire can be used to create open patches in a closing vegetation structure on abandoned land[93]. In Australia, Bowman[94] has suggested using taxon substitution to replace the lost megafauna to bring back their ecosystem impacts would reduce rampant forest fires that have become prevalent since the megafauna extinction. Detailed research of a forest fire in Switzerland provides details on impacts on local soil, tree resistance, post-fire colonization by plants and their species diversity[95].

3.3.3.3. Hydrology

Hydrology refers to the properties of water and its movement in relation to land. A wide variety of ecological processes influence hydrology and are in turn influenced by hydrology. Articles considering the restoration of hydrological processes, primarily through the restoration of wetland vegetation communities such as reedbeds and wet woodland are available[96–98]. Beaver and their dams impact hydrology and are discussed in 136 articles in the Bibliography. One of these articles looks at modelling the capacity of riverscapes to support beaver dams[99], which would be an important exercise for any proposed beaver reintroduction. An important human factor is the risk of flooding from different hydrological systems, and 95 articles currently consider this. Acreman et al. [100] found that wetlands in uplands generally generated floods, while wetlands in lowland areas help reduce floods, but that specific site conditions were important.

3.4. Species/Taxonomic Groups

Species reintroduction is a key tool to restore ecological processes. Species deliver ecological processes by interacting with each other and the environment. For example, predators, such as wolf, fox, white-tailed eagle, adder and wasp, provide the function of predation by hunting their prey. Herbivores, such as horse, European elk (aka moose), geese, caterpillars, provide herbivory through grazing and browsing vegetation. Pollinators, such as bees, butterflies, wasps, and beetles provide pollination by moving pollen between flowering plants while collecting or feeding on pollen and nectar. Less obviously, wild boar provide disturbance through rooting, which they use to dig up roots and invertebrates to eat. Different communities of vegetation alter hydrology. Sphagnum mosses are important for creating bogs. Woodland slows the flow of water through catchments. Animals can also play key roles. Beavers alter the flow water in streams by creating dams. Seed dispersal, the likelihood of fires starting and how they burn, and the rate of organic matter decomposition are all also affected by changing plant and animal communities.

Re-establishing functional communities of plants and animals is a central goal of rewilding. Achieving this on a broad scale requires knowledge and information on: the requirements of each plant and animal; understanding of how they will interact and change the current ecosystem; and, how society and the economy will respond to their return. The UK ratified the Bern Convention on the Conservation of

European Wildlife and Natural Habitats[1], undertaking to reintroduce native species of wild plants and animals if studies show it is effective and acceptable. Here we explore the knowledge available on the reintroduction and ecological importance of 21 species Rewilding Britain have suggested as candidates for reintroduction or population expansion.

3.4.1. Beaver

Beaver are famous dam-building ecosystem engineers and their importance to British ecology is topical as there are now wild beavers back in parts of Scotland[101,102] and Devon[103]. 'Beaver' was individually paired with 'Reintroduction' 'Ecosystem services', 'Ecosystem Disservices', 'Flooding', 'Water quality', 'Tourism', 'Public perception', 'Carbon sequestration', 'Soil protection' and 'Damage'. These search terms collectively resulted in 1443 article hits, 596 of which were deemed relevant and have been stored in the Bibliography under 'Beaver'.

Perhaps unusually compared to most species, the impact beaver have on ecosystems has also been extensively studied[104]. Research has highlighted the beavers ability to: alter the structure of the flow of fluvial systems[105], create a rich resource of deadwood[106], create ponds that are beneficial to amphibians[107], and create conditions that support rare species while also increasing regional species diversity[108]. Beavers are also reported to provide ecosystem services, including: alleviating downstream flooding (although there is little direct evidence of this currently stored in the Bibliography)[109], improving water quality[110,111], and attracting tourists[102,112]. Beaver also pose risks and costs, including: localised flooding[113–115], damage crops and forestry[69,116,117], and transmitting diseases[118]. Disease was not included as a search term, this is because the number of article hits was too great to be manageable in this project, and is needed to more fully understand the threat posed by beavers.

Searching for 'reintroduction' within the articles tagged beaver reveals 116 hits. These include accounts of reintroductions in Europe[115,119–125], proposals for reintroductions in England[11,126,127], Wales[128], and Scotland[129,130], as well as reports of the impact of reintroduction at Knapdale, Scotland[101,102]. Policy-makers in England have been proactive in assessing the feasibility of reintroducing beaver to England[131], to aid their decision making if and when they receive applications to reintroduce beaver.

Research in North America has used GIS modelling to estimate the likely density of beaver dams on different stretches of river[99]. This type of modelling allows for greater understanding of the likely implications of reintroducing beaver to any particular location. Applying this research to Britain would make an excellent MSc level project, and provide a valuable resource for considering where beavers could be reintroduced and the impacts they would have on biodiversity, flooding and water quality.

3.4.2. Bison

European bison have not been recorded in Britain during the Holocene. As a result they are considered a more controversial, 'Pleistocene Rewilding', candidate. 'Bison' was individually paired with 'Reintroduction', 'Ecosystem services' and 'Ecosystem disservices', resulting in 45 articles being searched. In total, 36 articles are included in the Bibliography. This includes many articles considering the American bison, which is a separate but related species.

European bison were driven extinct in the wild shortly after World War I. Reintroduction and conservation efforts recovered a wild population to 1,800 individuals by 2006[132]. A European bison rewilding plan, produced by Rewilding Europe, explores opportunities for reintroducing bison across Europe[133]. Research has also developed a protocol for mapping potential reintroduction sites for bison[134]. Genetics are also an important consideration in the reintroduction and conservation of European bison as a result of the small number of individuals that survived the post-WWII bottleneck[135,136]. The use of the managed-meta population concept has been proposed in the Ukraine to keep populations of European bison connected to each other because of the dispersal barriers between the populations[137]. A study in rural Lithuania, where bison had been reintroduced 40 years earlier, reported that public perceptions of bison were largely positive (85% of respondents), providing the animals were not within 10 km of their homes[138]. Research in North America has reported on the fate of bison after reintroduction, and found that survival was typically high (>80%)[139].

---

[1] http://jncc.defra.gov.uk/page-1364

The impacts of bison have been less widely considered, however, the impact of bison herbivory has been studied in places[92,140]. While disease was not specifically searched for a few articles discuss the challenges posed by diseases carried by bison, including Brucellosis and Foot and Mouth disease[141,142]. Bison are a member of the guild of large herbivores which have been reported to be important seed dispersers in Bialowiesa[74].

3.4.3. **European elk**

European elk are known as moose in North America despite both being the same species, *Alces alces*. Further confusion can occur because the animal known as elk in North America, *Cervus canadensis*, are a very close relative of red deer, *Cervus elaphus*, in Europe. These confounding names made searching for target articles for this species difficult. As a result they were not included in our search effort. However, other search terms did generate articles relevant to European elk, 35 in total.

A successful reintroduction of European elk is reported in Russia[143]. In terms of the impacts, European elk have been reported to be browser with implications for forestry, but also favoured quarry for hunters[144]. The interactions between wolves, moose and vegetation has been reported for Isle Royale for over 50 years, offering a very detailed study of this important trophic cascade pathway[145,146].

3.4.4. **Lynx**

The possible reintroduction of the Lynx to Britain is topical, with interest being generated by plans posed by the Lynx UK Trust. Notably the Lynx UK Trust have developed applications for permits to reintroduce lynx to Britain, including in England and Scotland[147–151]. Lynx was individually paired with the following search terms: 'Public perception', 'Depredation', and 'Tourism'. This generated 110 articles hits, with 58 articles stored in the Bibliography.

Research carried out in the Alps[152], Latvia[153], UK[151] have explored peoples attitudes toward lynx. It is reported that rural communities in the Alps are not prepared to alter their pastoral practices to allow coexistence with lynx[152]. People questioned in Latvia gave a generally positive view of large carnivores but felt their populations should be controlled[153]. In the UK, 91% of respondents that were proactive in offering their opinion of a possible lynx reintroduction supported the idea[151]. A second UK survey was conducted representing a public with a 'passive voice' that did not actively seek to provide an opinion. In this survey 53% of respondents supported reintroduction, and 17% opposed it[151].

Lynx killing of livestock, particularly sheep, is considerable concern with 34 articles discussing this issue. Some research describes the variable extent of the problem between regions[154–156], while other articles discuss mechanisms for reducing human-lynx conflict[157–161]. Tourism is presented as an important argument for supporting lynx reintroduction to Britain[162].

3.4.5. **Wild boar**

Wild boar have re-established themselves in Britain after an approximate 400 year absence[163]. 'Wild boar' was paired with 'Reintroduction', and 'Ecosystem services', generating 35 article hits. However, with articles gathered from other search terms, 75 articles are stored in the Bibliography.

The feasibility of reintroducing wild boar to Scotland has been researched[164,165], while research has explored free-living wild boar populations found in England[163]. Research has also explicitly considered the impact of wild boar on key vegetation communities in Britain, including blue bell woods[88], bracken and heather moorland adjacent to woodland[11,83,166]. Wild boar are reported to create 10s of m^2 of bare ground per week[83]. Disease is again a concern with this species[167–170]. Wild boar are considered an agricultural pest, but also a hunting resource[87,171].

3.4.6. **Wildcat**

Wildcat remains extant in Britain but its range is restricted to Scotland[172]. Reintroductions could be considered elsewhere in Britain. 'Wildcat' was paired with 'Reintroduction', 'Ecosystem services', and 'Tourism', resulting in 13 article hits. In total, with articles from other search terms, 15 articles have been included in the Bibliography. The articles include an account of wildcat reintroduction to Bavaria [173], and how wildcats can be captive bred for reintroduction[174]. The Lynx UK Trust discuss the threat lynx pose to wildcats if reintroduced to Scotland[175]. While others explore wildcat habitat selection and requirements, which include a preference for woodland, watercourses and meadows, while keeping a critical distance from villages, houses and roads[176–178].

3.4.7. Wolf

Wolf reintroduction to Yellowstone National Park, and the trophic cascades that have been associated to their return, is the iconic example of rewilding[47,179–181]. We paired 'wolf' with six different search terms, generating 571 hits (see Appendix A for details). In total 319 articles have been tagged wolf in the Bibliography. Of these, 124 refer to Yellowstone National Park, and 92 refer to a trophic cascade. Whether the loss or reintroduction of wolves can trigger trophic cascades is also discussed for Bialowieza[182], Jasper National Park[183], Grand Teton National Park[184], and Montana[185]. Depredation of livestock is referred to in 42 articles and public perceptions of the wolf are discussed in 47 articles. Wolf reintroduction to Britain is discussed in 7 articles[11,19,186–190]. The impact of wolves on tourism is discussed in 16 articless[191–193].

3.4.8. British birds

The British birds being considered for reintroduction or translocation by Rewilding Britain include **capercaillie** (8 articles), **common crane** (54), **eagle owl** (148), **goshawk** (2), **great bustard** (5), **night heron** (2), **osprey** (6), **Dalmatian pelican** (37), **spoonbill** (1), **white stork** (19), and **white-tailed eagle** (7). Each of these species was individually paired with 'Reintroduction' and 'Ecosystem services', further 'eagle-owl' was searched without a secondary search term, generating 244 articles that were searched, which led to 86 article being included in the Bibliography. For all the birds, articles consider natural expansion or reintroduction of capercaillie[194–196], common crane[197,198], eagle owl[199–201], goshawk[202], great bustard[203–205], night heron[203–205], osprey[206–208], Dalmatian pelican[209], white stork[125,210–213], and white-tailed eagle[214]. The ecological roles of these species have not been a focus of research stored in the Bibliography, only the predatory impacts of eagle owls is considered[215]. The ecosystem service or disservices impact of these species is also very poorly represented in the Bibliography, with the exception that white stork have been reported to have tourism value[216]. Most of the remaining articles describe the species' ecology and conservation. This provides a useful resource for considering the viability of reintroductions.

3.4.9. Marine species

A grey whale Atlantic reintroduction feasibility assessment exists for the Atlantic coast of Canada, and the report concludes reintroduction is not possible at this time because insufficient individuals are available for reintroduction[217]. The articles discussing Bluefin tuna almost exclusively discuss the species in relation to fishing. There are 22 articles discussing the ecology and conservation of sturgeon. This includes a variety of species from the genus *Acipenser*. There are a number of useful articles discussing the reintroduction of sturgeon across Europe[218,219]. Reintroducing Atlantic sturgeon to France has been highlighted as important to save the giant pearl mussel[220].

3.5. Rewilding Tools

A set of rewilding tools has yet to be defined. However, there are approaches that have been clearly associated to the different types of rewilding. Passive Rewilding is achieved by lessening human impacts on ecosystems[3]. This can occur by: 'land abandonment' (rewilding is a by product of land abandonment, rather than land abandonment being a tool); by undoing past human interventions like blocking a drainage ditch; or, by alleviating current human impacts such as hunting 'Impact alleviation'. Active Rewilding increases human interventions in the short-term in an attempt to restore ecological processes and so self-sustaining ecosystems in the long-term[10]. The literature indicates this can be achieved by seeding vegetation communities, to, for example, return a seed source that has been lost ('Physical restoration'), or by the 'reintroduction' of functioning guilds of animal[6]. The latter includes more typical conservation translocations, including 'reintroduction', but also more controversial techniques including 'back-breeding', 'assisted colonisation', 'taxon substitution' and 'de-extinction'. Where areas are too small for all ecological processes to be restored, human interventions maybe required to mimic ecological processes. For example, a 'managed-metapopulation' mimics species dispersal, by managers actively moving species between sites to overcome dispersal barriers.

We have limited our search on Land abandonment with a secondary search term, 'Britain'. The terms Physical or Habitat restoration are too broad to be effective search terms, so only relevant articles found through other search terms have been tagged 'Physical restoration'. Reintroduction has been the focus of a considerable body of research; the term scored 10,309 hits in Mendeley. As this was too many to be assessed, 'reintroduction' was paired with the species being considered for reintroduction by Rewilding

Britain. Far fewer hits were scored from the other, newer 'tools' of rewilding and these were searched individually. This section summaries the literature in the Bibliography relevant to these tools.

3.5.1. Land abandonment/Impact alleviation

Land abandonment is mostly discussed as a phenomenon of mainland Europe (rewilding is a by product of land abandonment, rather than land abandonment being a tool)[221]. In Britain the main example has been the managed retreat of the coastline at Abbots Hall Farm[222]. This example describes how allowing the sea to reclaim land, removing a human impact from the past, can restore natural processes that increase biodiversity, and offer new ecosystem services such as flood alleviation. This example also highlights that ecosystem services are often traded with land abandonment; while flood alleviation has been gained, it comes at the expense of food production.

3.5.2. Soil translocation

Organisms within soil are essential for creating and maintaining soil chemistry and its physical structure. Recent research has demonstrated that translocating soil from intact vegetation communities promotes the rapid restoration of impoverished plant communities [223]. It is hypothesised that this process is successful because of the translocation of living organisms within the soil that facilitate other ecological processes.

3.5.3. Physical/Habitat restoration

Habitat restoration is typically associated with traditional conservation. However, restoring vegetation communities can be important for re-establishing species interactions and so ecological processes. For example, the loss of plant diversity, and the associated variety of resources these species provide for herbivores, such as nectar, pollen, seeds, nuts, fruits, and leaves, has negative impacts on the diversity of consumers of these resources[224,225]. This supports policies aimed at restoring food plant diversity to vegetation communities. The Bumblebee Conservation Trust has published guidelines for the restoration of wildflower rich grasslands[226]. A book considers how forested wetlands can be restored, highlighting how early succession species can return naturally but that large seeded species like oak need to be planted because of deficient dispersal[98]. Other sites have mimicked beaver by constructing dam structures to restore river systems[227]. In each case, rewilders can consider whether these restoration efforts are: 1) seeking to alleviate past human impacts to restore ecological processes; or, 2) determining and maintaining ecosystems. The former is probably more accurately considered rewilding, while the latter ecological restoration. Both approaches are valid, but care must be taken to distinguish between the approaches. For example, James Fenton believes rewilding has become synonymous with reforesting in Scotland, and that forests are not the current natural vegetation community for Scotland[228].

3.5.4. Natural expansion

Many large mammals and birds are reportedly expanding their range in Europe[35,229]. Britain's island status means there is limited opportunity for this to occur here, except for species that can fly.

3.5.5. Reintroduction

Our searches, targeted at the reintroduction of species proposed for reintroduction by Rewilding Britain, resulted in 560 articles being added to the Bibliography. Of these, 244 discuss the reintroduction of the wolf, and 7 discuss the possibility and/or risks and opportunities of reintroducing wolves to Britain[11,19,186–189,230]. Other species have received less attention, for example, beaver were considered in 128 articles, bison in 53 articles, and capercaillie in 6. Despite the varying levels of research, it is clear that reintroduction is a common tool in conservation. Furthermore, new reintroduction and translocation guidelines are increasingly recognising the beneficial impact species can have on the ecosystems they are being reintroduced to. However, this has yet to translate into practical best-practice guidelines for the restoration of ecological processes through species reintroduction[29,231].

3.5.6. Back breeding

Back breeding is a structured breeding program to restore wild traits to domesticated species. The key example is an effort to create a breed of cattle with the traits of the extinct aurochs[1,2].

3.5.7. Taxon substitution

Taxon substitution, replacing extinct species with closely related species that have similar roles within an ecosystem, is a new and controversial translocation approach. It is typically associated with Pleistocene Rewilding[4]. The most well studied use of taxon substitution is from Mauritius, where surviving tortoises from neighbouring islands have been used to replace a lost tortoise, with interesting and positive implications for herbivory and non-native species control[232], and seed-dispersal[233]. The idea has also been used to restore more specific mutualisms, for example between a plant and pollinator in Hawaii[234]. Because of the risk of unexpected negative interactions, guidelines governing the use of taxon substitution have been devised, drawing on experience from biological control projects[235].

3.5.8. **Assisted colonisation**

Assisted colonisation is the translocation of species beyond their native range. It is typically used to move species to suitable habitat that they cannot colonise by their own dispersal mechanisms fast enough to avoid a threat, typically climate change. It is a tool that has been primarily proposed for the conservation of threatened species[236], but it has also been proposed as a tool to restore ecosystem function under climate change[237].

3.5.9. **De-extinction**

Currently, de-extinction (the resurrection of extinct species), is technically impossible. However, research is advancing in this area, and one day it may result in rewilders having the option of reintroducing formerly extinct species. There is discussion about selecting candidates for de-extinction and restoring them[238,239]. This has raised numerous challenging questions about whether such a course of action is appropriate[240], or ethically acceptable[241–243]. One of the most realistic opportunities is to use de-extinction to bring back the Pyrenean ibex[244]. Less controversially, it has also been suggested that the tools of de-extinction could help save critically endangered species and adapt to future changes by directly altering their DNA[245].

3.5.10. **Managed meta-population**

Small and isolated nature areas limit the processes that can be restored and the biodiversity that can be maintained[9]. A managed meta-population is where animal translocations are used to move animals between otherwise isolated populations[246]. This increases the effective connectivity of nature areas by allowing space hungry species, like apex carnivores, to be introduced and moved between relatively small and isolated reserves.

3.6. Impacts

Rewilding has been linked with a wide variety of positive and negative impacts. Discussed here is a selection of the more prominent ones.

3.6.1. **Biodiversity**

Biodiversity, short for biological diversity, is the "variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (Convention of Biological Diversity). There are clear goals at national and global levels to halt the decline in biodiversity by 2020[247]. Rewilding proponents have argued that rewilding will help halt and ultimately reverse the decline in biodiversity[248]. While rewilding skeptics fear embracing rewilding over large areas will be less effective at preserving biodiversity than targeted management, and, as a worst case scenario, fear rewilding could become part of the problem[3].

To broadly summarize, rewilding proponents reason that species evolved and survived in nature prior to human management, and so would do so again if appropriate ecological conditions can be created[3,6,11,248]. Those more skeptical of rewilding reason that current ecological communities are adapted to ecosystems that humans have been altering for millennia, by, for example, changing environmental conditions, driving species extinct, introducing new species, and altering habitat characteristics. They fear that removing the human effect or returning long lost ecological functions could negatively impact surviving species[14,22,27]. In response, rewilding proponents highlight that biodiversity is still in decline under current conditions and so a new approach is needed, while skeptics highlight that rewilding is unproven and that the rate of biodiversity decline could get worse without human management of nature.

The Bibliography contains 297 articles tagged as relevant to biodiversity conservation. The original rewilding article, by Soule and Noss[9], discusses how rewilding and traditional conservation management can be complimentary approaches to biodiversity conservation. Relatively small scale studies indicate that rewilding will result in some species doing better (winning) and others suffering (losing) as a result of rewilding in bird[93], moth and butterfly[249] communities. Other studies provide evidence that rewilding provides a net benefit for biodiversity, for example beavers are reported to facilitate whole-communities of water birds[250], provide support for frogs through out their life-cycle[251], and support a higher diversity of dragonflies and damselflies, molluscs and caddis flies[252]. A review of beaver impacts on ecosystems also reported mixed, but overall positive impact on fish populations[253]. However, other research indicates beavers can have a negative impact on native species in arid environments, by creating conditions that favor non-native species[254]. In other circumstances beavers can interact with heavily human-modified landscapes resulting in pollution events, as happened in Ontario when beavers blocked a spillway of a tailings dam causing dam failure and pollution of the river. However, the winners and losers of rewilding may be unpredictable, as has been seen at the rewilding project at Knepp Estate, Sussex[3].

A full and systematic review of the literature is needed to determine where the weight of evidence falls for the net biodiversity impacts of ecological process restoration. Considerable further research, over long timescales, considering a wide range of spatial scales, and covering a broad range of taxonomic groups is needed to fully evaluate the effect of rewilding on biodiversity. Such research will help practitioners predict when, where, and how rewilding can be an effective approach.

3.6.2. Carbon sequestration/emissions

It has been proposed that rewilding will result in the sequestration of carbon dioxide, particularly as a result of woodland regeneration on abandoned farmland[221]. For example, research from the Iberian peninsular suggests abandoned land can sequester significantly more carbon than either agricultural or already wild land[255]. However, "Globally, soils contain about three times the amount of carbon in vegetation and twice that in the atmosphere."[256] Thus, more complex interactions within the soil in response to rewilding might alter this prediction. The relationships also appear to be complicated, with even the restoration of peat lands reported to have mixed effects on carbon sequestration[257]. Thus natural woodland regeneration on peatlands is likely to result in carbon emissions[258]. Carbon sequestration has been associated with river actively engineered by beavers[259], however, beaver ponds have also been associated with carbon dioxide and methane emissions[260]. Analysis reported by the Natural Capital Committee indicates that planting 250,000 ha of woodland in each of England, Scotland and Wales could result in areas close to urban areas and away from peatland (afforestation in peatland can result in carbon emissions) would deliver a net economic benefit of nearly £550 million when accounting recreation and carbon sequestration benefits[258]. Improving the conditions that allow natural tree regeneration through rewilding could make this even more cost effective[261].

3.6.3. Flood alleviation/Flooding (Coast)

Coastal re-alignment, the removal of flood defences allowing the formation of natural features such as salt marshes, has become increasingly common in North America and Europe. Research looking at adapting to climate change in New Orleans suggests restoring wetlands would be worth billions of dollars per year[262]. Coastal re-alignment is being considered in England and Wales' climate change adaptation strategies[263]. Effort has been made to devise strategies for measuring the functioning of salt marshes in the context of their ecosystem service delivery[264]. However, research also indicates that restored salt marshes are not equivalent to natural salt marshes, with re-aligned coasts having more compact sediment, and significant differences in moisture and organic content[265].

3.6.4. Flood alleviation/Flooding (River)

A review of 25 natural flood management schemes revealed mixed results for flood alleviation depending on local characteristics[257]. Increased woodland coverage typically reduced peak flow, which was more pronounced for smaller rainfall events. Wetlands and floodplain restoration had the best results and caused fewer negative impacts. However, research comparing upland rain fed wetlands and flood plain found upland wetlands tend to be flood generating areas, while floodplain wetlands have greater potential to reduce floods[100]. Research from Pontbren, Wales, has indicated that the rate at which water infiltrates the soil was 67 times greater on land where sheep had been excluded and trees planted, compared to sheep pasture[266,267]. Beaver and their damming behaviour are often linked to flood alleviation ecosystem services, as their dams can increase water storage capacity of catchments, and reduce peak flows[268]. However, large beaver dams collapsing during heavy rainfall events can increase the threat posed by flooding[113]. Beavers also increase localised flooding, and methods have been devised to counter these localised problems[269].

3.6.5. Tourism

The natural environment, in its broadest sense, supports the lucrative outdoor recreation industry, worth £21 billion to the UK economy in 2012/13. Outdoor visitor spend is not evenly spread across the country, for example, the similarly sized Lake District and Yorkshire Dales National Parks attract ~£1146 million and ~£400 million a year in visitor spend respectively. Charismatic wildlife can attract additional tourists and increase visitor spend. Deinet et al. [35] offer a range of examples: Visitors seeking to see the osprey in Scotland spend £3.5 million per year. Tourism numbers have increased in Abruzzo, Italy, and Somiedo Natural Park, Spain, as a result of marketing campaigns focusing on bears and/or wolves. In Finland, a report indicated the number of wildlife watchers increased by 90% between 2005 and 2008, with majority wishing to see predators such as brown bear and wolverine. In South Africa, Clements et al. [270] report that a large reserve with megafauna is the most profitable ecotourism business model, while hunting reserves are less profitable.

3.6.6. Health

Human health benefits have been linked to people's interaction with nature. It is estimated that "if every household in England were provided with good access to quality green space it could save an estimated £2.1 billion in healthcare costs" [271]. A huge variety of activities attract the public to the outdoors [272]. Wild nature and increased opportunity to see exciting wildlife could diversify the types of outdoor experience available in Britain and inspire additional people to get outside more regularly to help realise the associated healthcare costs.

3.6.7. Management efficiency

Management of ecosystems, whether to preserve biodiversity, minimise ecosystem dis-services or maximise ecosystem services, is often expensive and perpetual. It is proposed that restoring ecological processes and systems can create the ecological conditions that support species, and balance the delivery of ecosystem services and dis-services so that management can be minimised[11,273]. Assessment of the changes in ecosystem service delivery at Wicken Fen highlights the cost-benefits of restoration on on-going management costs. Management costs are reported to have fallen by an estimated $1325 ha/year as a result of partial ecological restoration[274]. Elsewhere, beavers are reported to be a more cost-effective approach to creating deadwood than human management[106]. Beaver have also been proposed as a tool for implementing the EU Water Framework Directive[275]. Modelling to predict the density at which beavers will dam rivers would help predict the costs and benefits of beaver reintroduction, allowing them to be used as a restoration tool[99]. It has been suggested the reintroduction of predators could negate the need to control feral herbivores in western USA[276], and that wolf reintroduction to Scotland would save Highland estates costs of culling the deer herd[187]. Taxon substitute tortoises have controlled non-native plant species in Mauritius[232].

3.6.8. Soil protection

Soil degradation is estimated to be costing England and Wales £1.2 billion per year [277]. The causes include: erosion, compaction, loss of organic matter, loss of soil biodiversity, and diffuse contamination. In Pontbren, Wales, land with reduced herbivore density and planted trees is reported to have lower soil compaction, and 67 times faster water infiltration rates than grazed pasture [266]. Beaver dams trap sediment, but beaver digging access channels causes soil displacement[278]. Soil degradation with heavy grazing increases phosphorous pollution and salinization[279].

3.6.9. Water quality

Research by the Environment Agency suggests returning England's water bodies to a good ecological condition could generate benefits worth £21 billion over a 37-year period, for a cost of £16 billion[258]. These benefits could be achieved by self-restoring ecosystems where succession delivered more woodland, beavers restored wetlands, and drainage blocking and moss community re-seeding restored peatlands[11]. Beaver dams also act as a filter capturing pollutants such as agricultural fertilisers[111,280].

3.6.10. Damage to property

Wildlife threatens property through flooding, rooting, tree felling, and foraging. While beaver dams can help alleviate flooding downstream, they cause localised flooding. Localised flooding can kill crops and trees, destroy gardens, and damage buildings [281]. Wild boar cause damage to gardens, football pitches and golf courses [11].

3.6.11. **Depredations**

Some animals can present a direct threat to livestock. White-tailed eagle were reported to take between 33 to 37 lambs per year on the Isle of Mull between 1998 and 2002; a number thought not to be numerically significant for farming on the island when considering the thousands that typically die each year from other causes[282]. The threat large carnivores (such as lynx or wolf) would pose to livestock depends on the habitat, wild prey availability, and the level of livestock husbandry[283].

3.6.12. **Disease**

Wildlife harbour disease and can transmit pathogens to humans and livestock[11]. For example, Germany recorded 424 outbreaks of classical swine fever in their domestic pigs. Of the primary outbreaks, 59% were associated with infected wild boar[284]. Reintroduction guidelines highlight the importance of giving careful consideration to disease – for example in the beaver trial at Knapdale, Scotland, the animals were quarantined first and their health monitored annually during the 5-year trial[285]. Limiting the presence of some species in sensitive areas, such as wild boar near pig farms, would also help reduce conflicts. While species reintroduction associated to rewilding could increase the diversity and abundance of disease vectors the relationships are not simple: for example the reintroduction of predators can also reduce the prevalence of disease by reducing reservoir populations, particularly rodents[286].

4. Developing the science of rewilding

4.1. Developing the Rewilding Knowledge Hub Bibliography

4.1.1. We have presented some of the diverse knowledge that is available and relevant to rewilding. However, there is considerably more research available. More comprehensive and systematic reviews are needed to fully assess the knowledge available for each of our themes and sub-headings.

4.1.2. Our themes and sub-headings are also not exhaustive. Rewilding must draw from multiple disciplines, including, for example, social science, economics, law, and political science. We hope our initial efforts here will act as a springboard for establishing interdisciplinary projects.

4.1.3. Where systematic reviews identify knowledge gaps, empirical research is needed to fill these gaps. Areas that appear to require particular attention based on our review include:

- 4.1.3.1. Species functional roles in ecosystems
- 4.1.3.2. Systems based ecological restoration

4.1.4. Much of the knowledge we have presented relies on case studies. To move beyond case studies and to develop national or even continental rewilding strategies, the balanced evidence delivered from systematic reviews needs to applied to interdisciplinary projects to develop rewilding policy agendas.

4.2. Research gaps

Below are questions and project ideas that, based on our review of the literature, we think are particularly pertinent to our core themes of rewilding. However, because our review is not exhaustive a wider exploration of the literature is needed for every question. We have suggested these questions to provide inspiration for student projects, but we have not considered the suitability or plausibility of these questions to be answered as part of student projects.

Rewilding

4.2.1. What are the specific differences between passive, active and trophic rewilding approaches?

4.2.2. What are the key differences and implications of using a Pleistocene, Holocene and/or an Anthropocene baseline for rewilding?

4.2.3. How does rewilding differ from ecological restoration?

Geography

4.2.4. Compare and contrast how rewilding is being implemented across the world, in particular, consider the differences between the rewilding movements in North America and Europe.

4.2.5. Review, compare and contrast rewilding strategies for Britain, England, Scotland, and Ireland. Based on this review, develop options a rewilding strategy for Wales could consider.

Processes

4.2.6. How can we measure the functionality of ecological processes?

4.2.7. When do predators drive trophic cascades? Review the recorded ecological consequences of predator extinction, reintroduction, and re-colonisation to determine critical factors that predict when a trophic cascade will occur.

4.2.8. What trophic structure of predator and herbivore communities provides for biodiversity?

4.2.9. When should habitats be considered over-, or under-grazed? Review the conditions under which different landscapes are considered to be over- or under-grazed.

4.2.10. If and when are megaherbivores a requirement for developing a mosaic of open, transition and closed habitat types?

4.2.11. How intact are seed dispersal guilds?

4.2.12. Are certain plant species failing to colonise regions because a deficit in seed dispersers?

4.2.13. When and where is rooting by wild boar beneficial for biodiversity?

4.2.14. What is the cost-benefits of rooting?

4.2.15. Compare and contrast the prevalence of fire under Pleistocene, Holocene and Anthropocene baselines.

4.2.16. How important is fire in maintaining diverse vegetation community structures and wider biodiversity?

4.2.17. Can a fire ever be allowed to proceed unmanaged?

4.2.18. How can hydrological baselines be defined?

Species

For all species:

4.2.19. Where in Britain is it feasible to reintroduce the target species?

4.2.20. What are the predicted ecological, social, and economic consequences of the reintroduction of these species?

Species-specific examples:

4.2.21. Predict density at which reintroduced beavers would dam British rivers.

4.2.22. Model the ecosystem service and dis-service implications of beaver dam construction across the country.

4.2.23. Is it feasible to reintroduce bison to Britain despite it not occurring in Britain during the Holocene?

4.2.24. To what extent do bison fill the ecological niche of extinct Aurochs, or are wilder breeds of cattle more appropriate?

4.2.25. To what extent would reintroduced wolves and lynx pose a threat to extant native species of conservation concern?

4.2.26. Is it feasible to reintroduce wildcat to England and Wales?

Rewilding tools

4.2.27. What mechanisms can be used to encourage natural seed dispersal?

4.2.28. Are conservation NGOs already implementing rewilding: To what extent are conservation organisations already considering ecological process restoration in their management plans?

4.2.29. How risky is species reintroduction to restore missing ecological processes? What factors alleviate and exacerbate risk?

Impacts

4.2.30. Biodiversity: A full and systematic review of the literature is needed to determine where the weight of evidence falls for the net biodiversity impacts of ecological process restoration. Considerable further research, over long timescales, considering a wide range of spatial scales, and covering a broad range of taxonomic groups is needed to fully evaluate the effect of rewilding on biodiversity. Such research will help practitioners predict when, where, and how rewilding can be an effective approach.

4.2.31. When and where does rewilding result in greenhouse gas sequestration or emissions?

4.2.32. Where would coastline realignment result in a more cost efficient and practical solution to flood management?

4.2.33. Where would rewilding restore wetlands, where would these wetlands increase flood risk, and where would they decrease risk?

4.2.34. Where and when could the African big game ecotourism model be successfully applied in Britain?

4.2.35. Which wildlife attracts people to visit the outdoors regularly? Do those visitors gain health benefits?

4.2.36. What is the relationship between the size of a rewilding site and the ability to restore ecological processes?

4.2.37. Can rewilding help restore soils? Over what timescale can this be achieved?

4.2.38. How much would it cost in ecosystem dis-services if all candidate species were reintroduced to Britain? What options are there for mitigating these dis-services?

4.2.39. When do lynx primarily hunt wild prey, and when do they kill livestock? Compare and contrast reported lynx diet under different conditions.

4.2.40. Quantify the threat reintroduced animals could pose to Britain through host reintroduction.

5. References

1. Faris, S. Breeding Ancient Cattle Back from Extinction. *Time* 2–3 (2010). at <http://www.time.com/time/health/article/0,8599,1961918,00.html>
2. Drake, C. What the Heck? *Quantumbiologist* **2010,** (2010).
3. Lorimer, J. *et al.* Rewilding: Science, Practice, and Politics. *Annu. Rev. Environ. Resour.* **40,** 150902153650003 (2014).
4. Donlan, C. J. Pleistocene Rewilding: *Am. Nat.* 660–681 (2006).
5. Hansen, D. M., Donlan, C. J., Griffiths, C. J. & Campbell, K. J. Ecological history and latent conservation potential: Large and giant tortoises as a model for taxon substitutions. *Ecography (Cop.).* **33,** 272–284 (2010).
6. Svenning, J.-C. *et al.* Science for a wilder Anthropocene -synthesis and future directions for rewilding research. *Proc. Natl. Acad. Sci. U. S. A.* 1–7 (2015). doi:10.1073/pnas.1502556112
7. Burns, F. *et al. State of Nature report*. *The State of Nature partnership* (2013). at <https://www.rspb.org.uk/Images/stateofnature_tcm9-345839.pdf>
8. Watson, R., S. Albon, R. Aspinall, M. Austen, B. Bardgett, I. Bateman, P. Berry, W. Bird, R. Bradbury, and C. B. *National Ecosystem Assessment: understanding nature's value to society. Synthesis of key findings.* (2011).
9. Soulé, M. E. & Noss, R. F. Rewilding and Biodiversity: Complementary Goals for Continental Conservation. *Wild Earth* **8,** 19–28 (1998).
10. Sandom, C., Donlan, C. J., Svenning, J. & Hansen, D. in *Key Topics in Conservation Biology 2* 430–451 (2013).
11. Sandom, C. J. & Macdonald, D. W. in *Wildlife Conservation on Farmland Volume 1: Managing for Nature in Lowland Farms* (eds. Macdonald, D. W. & Feber, R. E.) 291 (2015).
12. Van der Wall, R. *et al.* in *UK National Ecosystem Assessment* (ed. S. Albon, K. Turner, and R. W.) (UNEP-WCMC, LWEC, UK, 2014).
13. Burns, P. *Natural flood management and rewilding*. (2016). at <http://www.ceh.ac.uk/news-and-media/blogs/natural-flood-management-and-rewilding-bbc-radio-4-today-programme>
14. Nogués-Bravo, D., Simberloff, D., Rahbek, C. & Sanders, N. J. Rewilding is the new pandora's box in conservation. *Current Biology* **26,** R87–R91 (2016).
15. Hintz, J. Some Political Problems for Rewilding Nature. *Ethics, Place Environ.* **10,** 177–216 (2007).
16. Linnell, J. D. C., Kaczensky, P., Wotschikowsky, U., Lescureux, N. & Boitani, L. Framing the relationship between people and nature in the context of European conservation. *Conservation Biology* (2015). doi:10.1111/cobi.12534
17. Richmond, O. M. W., McEntee, J. P., Hijmans, R. J. & Brashares, J. S. Is the climate right for pleistocene rewilding? using species distribution models to extrapolate climatic suitability for mammals across continents. *PLoS One* **5,** 1–11 (2010).
18. Smith, C. I. Re-wilding: introductions could reduce biodiversity. *Nature* **437,** 2005 (2005).
19. Wilson, C. J. Could we live with reintroduced large carnivores in the UK? *Mamm. Rev.* **34,** 211–232 (2004).
20. Donlan, J. Re-wilding North America. *Nature* **436,** 913–914 (2005).
21. Sandom, C., Faurby, S., Sandel, B. & Svenning, J.-C. Global late Quaternary megafauna extinctions linked to humans, not climate change. *Proc. R. Soc. London B Biol. Sci.* **281,** 20133254 (2014).
22. Oliveira-Santos, L. G. R. & Fernandez, F. A. S. Pleistocene rewilding, frankenstein ecosystems, and an alternative conservation agenda. *Conservation Biology* **24,** 4–5 (2010).
23. Wolverton, S. The North American Pleistocene overkill hypothesis and the re-wilding debate. *Divers. Distrib.* **16,** 874–876 (2010).

24. Jaffe, E. The debate over rewilding North America with ancient animals. *Sci. News* **170,** (2006).

25. Toledo, D., Agudelo, M. S. & Bentley, A. L. The shifting of ecological restoration benchmarks and their social impacts: Digging deeper into Pleistocene re-wilding. *Restor. Ecol.* **19,** 564–568 (2011).

26. Schlaepfer, M. a. Re-wilding: a bold plan that needs native megafauna. *Nature* **437,** 951 (2005).

27. Rubenstein, D. R., Rubenstein, D. I., Sherman, P. W. & Gavin, T. A. Pleistocene Park: Does re-wilding North America represent sound conservation for the 21st century? *Biol. Conserv.* **132,** 232–238 (2006).

28. Caro, T. The Pleistocene re-wilding gambit. *Trends in Ecology and Evolution* **22,** 281–283 (2007).

29. IUCN/SSC. *Guidelines for Reintroductions and Other Conservation Translocations.* (2013).

30. Kitchener, A. C. Re-wilding Ireland: restoring mammalian diversity or developing new mammalian communities? *Irish Nat. J.* 4–13 (2012). at <<Go to ISI>://BIOABS:BACD201300177804>

31. Lorimer, J. & Driessen, C. Wild experiments at the Oostvaardersplassen: Rethinking environmentalism in the Anthropocene. *Trans. Inst. Br. Geogr.* **39,** 169–181 (2014).

32. Gillson, L. *Conclusions: Conservation in the Anthropocene*. *Biodiversity Conservation and Environmental Change: Using palaeoecology to manage dynamic landscapes in the Anthropocene* (2015). doi:10.1093/acprof:oso/9780198713036.003.0008

33. Bull, J. W. & Maron, M. How humans drive speciation as well as extinction. *Proc. R. Soc. B* **283,** (2016).

34. Pereira, H. M. & Navarro, L. M. *Rewilding European landscapes*. *Rewilding European Landscapes* (Springer International Publishing, 2015). doi:10.1007/978-3-319-12039-3

35. Deinet, S. *et al.* Wildlife Comeback in Europe. *Wildl. comeback Eur. Recover. Sel. mammal bird species* 216–221 (2013).

36. Cronon, W. *The riddle of the Apostle Islands*. (2003).

37. Ripple, W. J. & Beschta, R. L. Trophic cascades in Yellowstone: The first 15 years after wolf reintroduction. *Biol. Conserv.* **145,** 205–213 (2012).

38. Johnson, C. N. Red in tooth and claw: How top predators shape terrestrial ecosystems. *Journal of Animal Ecology* **79,** 723–725 (2010).

39. Mäntylä, E., Klemola, T. & Laaksonen, T. Birds help plants: A meta-analysis of top-down trophic cascades caused by avian predators. *Oecologia* **165,** 143–151 (2011).

40. Sutherland, W. J. Conservation biology: openness in management. *Nature* **418,** 834–835 (2002).

41. Brown, C., Mcmorran, R. & Price, M. F. Rewilding – A New Paradigm for Nature Conservation in Scotland? *Scottish Geogr. J.* **127,** 288–314 (2011).

42. Connell, J. H. & Slatyer, R. O. Mechanisms of Succession in Natural Communities and Their Role in Community Stability and Organization. *Am. Nat.* **111,** 1119 (1977).

43. Estes, J. a *et al.* Trophic downgrading of planet Earth. *Science* **333,** 301–306 (2011).

44. Svenning, J.-C. A review of natural vegetation openness in north-western Europe. *Biol. Conserv.* **104,** 133–148 (2002).

45. Webb. *Managing for species Natural England Research Report NERR024*. (2010). doi:ISSN 1754-1956

46. Sandom, C. J., Ejrnæs, R., Hansen, M. D. D. & Svenning, J.-C. High herbivore density associated with vegetation diversity in interglacial ecosystems. *Proc. Natl. Acad. Sci. U. S. A.* **111,** 4162–7 (2014).

47. Ripple, W. J. & Beschta, R. L. Trophic cascades in Yellowstone: The first 15years after wolf reintroduction. *Biol. Conserv.* **145,** 205–213 (2012).

48. Gervasi, V. *et al.* Predicting the potential demographic impact of predators on their prey: A comparative analysis of two carnivore-ungulate systems in Scandinavia. *J. Anim. Ecol.* **81,** 443–454 (2012).

49. Ripple, W. J. *et al.* Status and ecological effects of the world's largest carnivores. *Science (80-.).* **343,** 1241484 (2014).

50. Barber-Meyer, S. M., Mech, L. D. & White, P. J. Elk calf survival and mortality following wolf restoration to Yellowstone National Park. *Wildl. Monogr.* **169,** 1–30 (2008).

51. Ripple, W. J. & Beschta, R. L. Restoring Yellowstone's aspen with wolves. *Biol. Conserv.* **138,** 514–519 (2007).

52. Eberhardt, L. L., Garrott, R. A., Smith, D. W., White, P. J. & Peterson, R. O. Assessing the impact of wolves on ungulate prey. *Ecol. Appl.* **13,** 776–783 (2003).

53. Kauffman, M. J., Brodie, J. F. & Jules, E. S. Are wolves saving Yellowstone's aspen? A landscape-level test of a behaviorally mediated trophic cascade. *Ecology* **91,** 2742–2755 (2010).

54. Beyer, H. L., Merrill, E. H., Varley, N. & Boyce, M. S. Willow on Yellowstone's Northern Range : Evidence for a Trophic Cascade ? *Ecol. Appl.* **17,** 1563–1571 (2007).

55. Johnson, C. N. & Vanderwal, J. Evidence that dingoes limit abundance of a mesopredator in eastern Australian forests. *J. Appl. Ecol.* **46,** 641–646 (2009).

56. Ritchie, E. G. & Johnson, C. N. Predator interactions, mesopredator release and biodiversity conservation. *Ecol. Lett.* **12,** 982–998 (2009).

57. Newsome, T. M. & Ripple, W. J. A continental scale trophic cascade from wolves through coyotes to foxes. *J. Anim. Ecol.* **84,** 49–59 (2015).

58. Hebblewhite, M. *et al.* Human activity mediates a trophic cascade caused by wolves. *Ecology* **86,** 2135–2144 (2005).

59. Serrouya, R., Mclellan, B. N. & Boutin, S. Testing predator-prey theory using broad-scale manipulations and independent validation. *J. Anim. Ecol.* **84,** 1600–1609 (2015).

60. Ford, A. T. *et al.* Recovery of African wild dogs suppresses prey but does not trigger a trophic cascade. *Ecology* **96,** 2705–2714 (2015).

61. Baker, A. G., Bhagwat, S. A. & Willis, K. J. Do dung fungal spores make a good proxy for past distribution of large herbivores? *Quat. Sci. Rev.* **62,** 21–31 (2013).

62. Vera, F. W. M. *Grazing ecology and Forest History*. (2000).

63. Daskin, J. H., Stalmans, M. & Pringle, R. M. Ecological legacies of civil war: 35-year increase in savanna tree cover following wholesale large-mammal declines. *Journal of Ecology* (2015). doi:10.1111/1365-2745.12483

64. Kintisch, E. & Linder, C. Born to rewild. *Science (80-.).* **350,** 1148–1151 (2015).

65. Willerslev, E. *et al.* Fifty thousand years of Arctic vegetation and megafaunal diet. *Nature* **506,** 47–51 (2014).

66. Griffiths, C. J. *et al.* The use of extant non-indigenous tortoises as a restoration tool to replace extinct ecosystem engineers. *Restor. Ecol.* **18,** 1–7 (2010).

67. Anderson, C. E., Chapman, K. A., White, M. A. & Cornett, M. W. Effects of browsing control on establishment and recruitment of eastern white pine (Pinus strobus L.) at Cathedral Grove, Lake Superior Highlands, Minnesota, USA. *Nat. Areas J.* **22,** 202–210 (2002).

68. RSPB. *Managing horse pastures for birds in the Peak District*. at <http://www.rspb.org.uk/Images/horsemanagement_tcm9-137278.pdf>

69. Loeb, R. E., King, S. & Helton, J. Human pathways are barriers to beavers damaging trees and saplings in urban forests. *Urban For. Urban Green.* **13,** 290–294 (2014).

70. Avilés, J. M., Sánchez, J. M. & Parejo, D. Food selection of wintering common cranes (Grus grus) in holm oak (Quercus ilex) dehesas in south-west Spain in a rainy season. *J. Zool.* **256,** 71–79 (2006).

71. Ripple, W. J. *et al.* Collapse of the world's largest herbivores. *Sci. Adv.* **1,** e1400103–e1400103 (2015).

72. Natural Engalnd. Re-introducing natural grazing: Natural England evidence. (2014). at <http://publications.naturalengland.org.uk/publication/5776149355429888?category=49001>

73. Pires, M. M. *et al.* Reconstructing past ecological networks: The reconfiguration of seed-dispersal interactions after megafaunal extinction. *Oecologia* **175,** 1247–1256 (2014).

74. Jaroszewicz, B., Piroznikow, E. & Sondej, I. Endozoochory by the guild of ungulates in Europe's primeval forest. *For. Ecol. Manage.* **305,** 21–28 (2013).

75. Mart??nez, D. & Garc??a, D. Changes in the fruiting landscape relax restrictions on endozoochorous tree dispersal into deforested lands. *Appl. Veg. Sci.* **18,** 197–208 (2015).

76. Birks, H. J. B. Mind the gap: How open were European primeval forests? *Trends in Ecology and Evolution* **20,** 154–156 (2005).

77. Hambler, C., Henderson, P. A. & Speight, M. R. Extinction rates, extinction-prone habitats, and indicator groups in Britain and at larger scales. *Biol. Conserv.* **144,** 713–721 (2011).

78. Trees for Life. (2016). at <http://treesforlife.org.uk>

79. Scott, D., Welch, D., Thurlow, M. & Elston, D. A. Regeneration of Pinus sylvestris in a natural pinewood in NE Scotland following reduction in grazing by Cervus elaphus. *For. Ecol. Manage.* **130,** 199–211 (2000).

80. Torroba-Balmori, P., Zald??var, P., Alday, J. G., Fern??ndez-Santos, B. & Mart??nez-Ruiz, C. Recovering Quercus species on reclaimed coal wastes using native shrubs as restoration nurse plants. *Ecol. Eng.* **77,** 146–153 (2015).

81. Badano, E. I., Samour-Nieva, O. R. & Flores, J. Emulating nurse plants to restore oak forests. *Ecol. Eng.* **37,** 1244–1248 (2011).

82. Marshall, K. N., Hobbs, N. T. & Cooper, D. J. Water Limits the Effects of Apex Predator Reintroduction on a Riparian Ecosystem. *Proc. R. Soc. Popul. Community Ecol.* **4,** (2013).

83. Sandom, C. J., Hughes, J. & Macdonald, D. W. Rooting for rewilding: Quantifying wild boar's sus scrofa rooting rate in the scottish highlands. *Restor. Ecol.* **21,** 329–335 (2013).

84. Alexiou, P. . Effect of feral pigs (Sus scrofa) on subalpine vegetation at Smokers Gap, ACT. *Proc. Ecol. Soc. Aust.* **12,** 135–142 (1983).

85. Schley, L. & Roper, T. J. Diet of wild boar Sus scrofa in Western Europe, with particular reference to consumption of agricultural crops. *Mamm. Rev.* **33,** 43–56 (2003).

86. Barrios-Garcia, M. N. & Ballari, S. A. Impact of wild boar (Sus scrofa) in its introduced and native range: A review. *Biol. Invasions* **14,** 2283–2300 (2012).

87. Wilson, C. J. Rooting damage to farmland in Dorset, southern England, caused by feral wild boar Sus scrofa. *Mamm. Rev.* **34,** 331–335 (2004).

88. Sims, N. K., John, E. A. & Stewart, A. J. A. Short-term response and recovery of bluebells (Hyacinthoides non-scripta) after rooting by wild boar (Sus scrofa). *Plant Ecology* (2014). doi:10.1007/s11258-014-0397-9

89. Rule, S. *et al.* The aftermath of megafaunal extinction: ecosystem transformation in Pleistocene Australia. *Science (80-.).* **335,** 1483–1486 (2012).

90. Gill, J. L., Williams, J. W., Jackson, S. T., Lininger, K. B. & Robinson, G. S. Pleistocene megafaunal collapse, novel plant communities, and enhanced fire regimes in North America. *Science (80-.).* **326,** 1100–1103 (2009).

91. Seager, S. T., Eisenberg, C. & St. Clair, S. B. Patterns and consequences of ungulate herbivory on aspen in western North America. *For. Ecol. Manage.* **299,** 81–90 (2013).

92. Fuhlendorf, S. D., Engle, D. M., Kerby, J. & Hamilton, R. Pyric herbivory: Rewilding landscapes through the recoupling of fire and grazing. *Conserv. Biol.* **23,** 588–598 (2009).

93. Regos, A. *et al.* Rural abandoned landscapes and bird assemblages: winners and losers in the rewilding of a marginal mountain area (NW Spain). *Reg. Environ. Chang.* **16,** 199–211 (2016).

94. Bowman, D. Conservation: Bring elephants to Australia? *Nature* **482,** 30–30 (2012).

95. Wohlgemuth, T. *et al.* Living with forest fires. *Not. pour le Prat.* (2010).

96. White, G., Self, M. & Blyth, S. *Bringing Reedbeds to Life : creating and managing reedbeds for wildlife.* at <http://www.rspb.org.uk/Images/bringing_reedbeds_to_life_tcm9-385799.pdf>

97. Wilcox, D. A., Sweat, M. J., Carlson, M. L. & Kowalski, K. P. A water-budget approach to restoring a sedge fen affected by diking and ditching. in *Journal of Hydrology* **320,** 501–517 (2006).

98. Craft, C. in *Creating and Restoring Wetlands* 129–160 (2016). doi:10.1016/B978-0-12-407232-9.00006-3

99. Macfarlane, W. W. *et al.* Modeling the capacity of riverscapes to support beaver dams. *Geomorphology* (2015). doi:10.1016/j.geomorph.2015.11.019

100. Acreman, M. & Holden, J. How wetlands affect floods. *Wetlands* **33,** 773–786 (2013).

101. Goodman, G. *et al.* Establishment of a Health Surveillance Program for Reintroduction of the Eurasian Beaver (Castor Fiber) into Scotland. *J. Wildl. Dis.* **48,** 971–978 (2012).

102. Moran, D. & Hanley-Nickolls, R. *The Scottish Beaver Trial: Socio-economic monitoring - First Report. Scottish Natural Heritage Commissioned Report No. 482* (2011).

103. Devon Wildlife Trust. The Devon Beaver Project. The story so far... *Devon Wildl. Trust* (2011). at <http://www.devonwildlifetrust.org/publications/>

104. Rosell, F., Bozsér, O., Collen, P. & Parker, H. Ecological impact of beaers Castor fiber and Castor canadensis and their ability to modify ecosystems. *Mamm. Rev.* **35,** 248–276 (2005).

105. Puttock, A., Cunliffe, A. M., Anderson, K. & Brazier, R. E. Aerial photography collected with a multirotor drone reveals impact of Eurasian beaver reintroduction on ecosystem structure. *J. Unmanned Veh. Syst.* **3,** 123–130 (2015).

106. Thompson, S., Vehkaoja, M. & Nummi, P. Beaver-created deadwood dynamics in the boreal forest. *For. Ecol. Manage.* **360,** 1–8 (2016).

107. Vehkaoja, M. & Nummi, P. Beaver facilitation in the conservation of boreal anuran communities. *Herpetozoa* **28,** 75–87 (2015).

108. Bartel, R. A. Effects of disturbance on habitat dynamics of a rare species. *ProQuest Dissertations and Theses* (2008). at <http://search.proquest.com/docview/304541270?accountid=10979\nhttp://www.redi-bw.de/links/unifr?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:dissertation&genre=dissertations+&+theses&sid=ProQ:ProQuest+Dissertations+&+Theses+A&I&atitle=&title=Effec>

109. Westbrook, C. J., Cooper, D. J. & Butler, D. R. in *Treatise on Geomorphology* **12,** 293–306 (2013).

110. Szpikowska, G. & Szpikowski, J. Physicochemical properties of beaver wetlands water in the Kłuda Valley. *Monit. Środowiska Przyr.* **13,** 95–101 (2012).

111. Maret, T. J., Parker, M. & Fannin, T. E. The effect of beaver ponds on the nonpoint source water quality of a stream in Southwestern Wyoming. *Water Res.* **21,** 263–268 (1987).

112. Halley, D. J. J. & Rosell, F. The beaver ' s reconquest of Eurasia : status , population development and management of a conservation success. *Mamm. Rev.* **32,** 153–178 (2002).

113. Butler, D. R. The failure of beaver dams and resulting outburst flooding: a geomorphic hazard of the southeastern Piedmont. *Geographical Bulletin - Gamma Theta Upsilon* **31,** 29–38 (1989).

114. Reddoch, J. M. & Reddoch, A. H. Consequences of beaver, Castor canadensis, flooding on a small shore fen in Southwestern Quebec. *Can. Field-Naturalist* **119,** 385–394 (2005).

115. Elmeros, M., Madsen, A. B. & Berthelsen, J. P. Monitoring of reintroduced beavers (Castor fiber) in Denmark. *Lutra* **46,** 153–162 (2003).

116. Härkönen, S. Forest damage caused by the Canadian beaver (Castor canadensis) in South Savo, Finland. *Silva Fenn.* **33,** 247–259 (1999).

117. Shwiff, S. A., Kirkpatrick, K. N. & Godwin, K. Economic evaluation of beaver management to protect timber resources in Mississippi. *Human-Wildlife Interact.* **5,** 306–314 (2011).

118. Dunlap, B. G. & Thies, M. L. Giardia in beaver (Castor canadensis) and nutria (Myocastor coypus) from east Texas. *J. Parasitol.* **88,** 1254–1258 (2002).

119. Zavyalov, N. A., Zheltukhin, A. S. & Korablev, N. P. The beavers of the Tyudma River (Central Forest State Biosphere Reserve, Russia): from a reintroduction to a 'ideal' population. *Byulleten' Mosk. Obs. Ispyt. Prir. Otd. Biol.* **116,** 12–23 (2011).

120. Dzięciołowski, R. & Gozdziewski, J. in *Beaver Protection, Management and Utilization in Europe and North America* 31–35 (1999). doi:10.1007/978-1-4615-4781-5_6

121. Frosch, C. *et al.* The genetic legacy of multiple beaver reintroductions in central Europe. *PLoS One* **9,** (2014).

122. Żurowski, W. Preliminary Results of European Beaver Réintroduction in the Tributary Streams of the Vistula River. *Acta Theriol. (Warsz).* **24,** 85–91 (1979).

123. Sluiter, H. The reintroduction and the present status of the beaver (Castor fiber) in the Netherlands: an overview. *Lutra. 2003 December;* **46,** 129–133 (2003).

124. Schwab, G. & Lutschinger, G. The return of the beaver (Castor fiber) to the Danube watershed. in *The European Beaver in a new millennium. Proceedings of 2nd European Beaver Symposium, 27-30 Sept. 2000* 47–50 (2001).

125. Lecomte, J., Bigan, M. & Barre, V. Re-introducing and strengthening animal populations in France. (In French). in *Proceedings of theSaint Jean du Gard symposium* 350 (1990). at <http://www.scopus.com/scopus/inward/record.url?eid=2-s2.0-0025590756&partnerID=40&rel=R5.6.0>

126. O'Connell, M. J., Atkinson, S. R., Gamez, K., Pickering, S. P. & Dutton, J. S. Forage preferences of the European Beaver Castor fiber: Implications for re-introduction. *Conserv. Soc.* **6,** 190–194 (2008).

127. South, A. B., Rushton, S. P., Macdonald, D. W. & Fuller, R. Reintroduction of the European beaver (Castor fiber) to Norfolk, UK: a preliminary modelling analysis. *J. Zool.* **254,** 473–479 (2001).

128. Jones, A. C. ., Halley, D. J., Gow, D., Branscombe, J. & Aykroyd, T. Welsh Beaver Reintroduction Assessment (full report). 1 to 105 (2012). doi:10.1007/s13398-014-0173-7.2

129. South, A., Rushton, S. & MacDonald, D. Simulating the proposed reintroduction of the European beaver (Castor fiber) to Scotland. *Biol. Conserv.* **93,** 103–116 (2000).

130. Macdonald, D. W. *et al.* Reintroducing the beaver (Castor fiber) to Scotland: a protocol for identifying and assessing suitable release sites. *Anim. Conserv.* **3,** 125–133 (2000).

131. Natural England. *The feasibility and acceptability of reintroducing the European beaver to England (NECR002).* (2009). at <http://publications.naturalengland.org.uk/publication/45003>

132. Olech, W. *Bison bonasus. The IUCN Red List of Threatened Species 2008: e.T2814A9484719.* (2008). at <http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T2814A9484719.en.>

133. van de Vlasakker, J. *Rewilding Europe Bison Rewilding Plan, 2014-2024.* (2014). at <https://www.rewildingeurope.com/wp-content/uploads/2014/10/Bison-Rewilding-Plan-2014.pdf>

134. Bleyhl, B. *et al.* Mapping seasonal European bison habitat in the Caucasus Mountains to identify potential reintroduction sites. *Biol. Conserv.* **191,** 83–92 (2015).

135. Tokarska, M. *et al.* Genetic variability in the European bison (Bison bonasus) population from Białowieża forest over 50 years. *Biol. J. Linn. Soc.* **97,** 801–809 (2009).

136. Olech, W. & Perzanowski, K. A genetic background for reintroduction program of the European bison (Bison bonasus) in the Carpathians. *Biol. Conserv.* **108,** 221–228 (2002).

137. Perzanowski, K., Olech, W. & Kozak, I. Constraints for re-establishing a meta-population of the European bison in Ukraine. *Biol. Conserv.* **120,** 349–357 (2004).

138. Balčiauskas, L. & Kazlauskas, M. Forty years after reintroduction in a suboptimal landscape: Public attitudes towards European bison. *Eur. J. Wildl. Res.* **60,** 155–158 (2014).

139. Pyne, M. I. *et al.* Survival and Breeding Transitions for a Reintroduced Bison Population: a Multistate Approach. *J. Wildl. Manage.* **74,** 1463–1471 (2010).

140. Kwiatkowska, A. J. The changing pressure of herbivores as the cause of decline of heliophilous oak forest in the Bialowieza Primeval Forest. *Wiad. Ekol.* **42,** 137–162 (1996).

141. Davis, D. S. & Elzer, P. H. Brucella vaccines in wildlife. *Vet. Microbiol.* **90,** 533–544 (2002).

142. Paprocka, G. & Kesy, A. Risk of disseminating of foot-and-mouth disease virus by wildlife. *Med. Weter.* **68,** 333–337 (2012).

143. Sipko, T. P. STATUS OF REINTRODUCTIONS OF THREE LARGE HERBIVORES IN RUSSIA. *Alces* **45,** 35–42 (2009).

144. Sandström, C., Di Gasper, S. W. & Öhman, K. Conflict resolution through ecosystem-based management: The case of Swedish moose management. *Int. J. Commons* **7,** 549–570 (2013).

145. Shipley, L. A. Fifty years of food and foraging in moose: lessons in ecology from a model herbivore. *Alces* **46,** 1–13 (2010).

146. McInnes, P. F., Naiman, R. J., Pastor, J. & Cohen, Y. Effects of moose browsing on vegetation and litter of the boreal forest, Isle Royale, Michigan, USA. *Ecology* **73,** 2059–2075 (1992).

147. White, C. Analysis for the Reintroduction of Lynx To the UK: Main Report. 1–48 (2015).

148. Smith, D. & Convery, I. Lynx UK Trust – A National Stakeholder Consultation: An Interim Consultation Document. 1–32 (2016).

149. Eagle, A. & Chance, C. Lynx UK Trust's Proposal for a Trial Reintroduction. 1–11 (2015).

150. Smith, D. & Convery, I. Application to Natural England for the Trial Reintroduction of Lynx to England. 1–75 (2015).

151. Smith, D. & Convery, I. Reintroduction of the Eurasian Lynx to the United Kingdom: Results of a Public Survey. 1–30 (2016).

152. Breitenmoser, U. Large predators in the Alps: The fall and rise of man's competitors. in *Biological Conservation* **83,** 279–289 (1998).

153. Andersone, Ž. & Ozolinš, J. Public perception of large carnivores in Latvia. *Ursus* **15,** 181–187 (2004).

154. Odden, J. *et al.* Lynx depredation on domestic sheep in Norway. *J. Wildl. Manage.* **66,** 98–105 (2002).

155. Gervasi, V., Nilsen, E. B., Odden, J., Bouyer, Y. & Linnell, J. D. C. The spatio-temporal distribution of wild and domestic ungulates modulates lynx kill rates in a multi-use landscape. *J. Zool.* **292,** 175–183 (2014).

156. Molinari, P. *et al.* Status of the Eurasian lynx (_Lynx lynx_) in the Italian Alps: an overview 2000-2004. *Acta Biol. Slov.* **49,** 13–18 (2006).

157. Garrote, G. *et al.* Effectiveness of electric fences as a means to prevent Iberian lynx (Lynx pardinus) predation on lambs. *Hystrix, the Italian Journal of Mammalogy* **26,** 61–62 (2015).

158. Herfindal, I. *et al.* Does recreational hunting of lynx reduce depredation losses of domestic sheep? *J. Wildl. Manage.* **69,** 1034–1042 (2005).

159. Karlsson, J. & Johansson, Ö. Predictability of repeated carnivore attacks on livestock favours reactive use of mitigation measures. *J. Appl. Ecol.* **47,** 166–171 (2010).

160. Haugerud, R. E. Reindeer husbandry and the surrounding world. in *Rangifer* **13,** 1–132 (2009).

161. Linnell, J. D. C. *et al.* The Linkage between conservation strategies for large carnivores and biodiversity: the view from the 'half-full' forests of Europe. *Large Carniv. Conserv. Biodiverstiy* 381–398 (2005).

162. Appendix, S. S. Cost-Benefit Analysis for the Reintroduction of Lynx To the Uk: Site Selection Appendix. (2015).

163. Goulding, M. J. M. J., Roper, T. J. T. J., Smith, G. G. C. & Baker, S. J. S. Presence of free-living wild boar Sus scrofa in southern England. *Wildlife Biol.* **9,** 15–20 (2003).

164. Howells, O. & Edwards-Jones, G. A feasibility study of reintroducing wild boar Sus scrofa to Scotland: Are existing woodlands large enough to support minimum viable populations. *Biol. Conserv.* **81,** 77–

89 (1997).

165. Leaper, R., Massei, G., Gorman, M. L. & Aspinall, R. The feasibility of reintroducing Wild Boar (Sus scrofa) to Scotland. *Mamm. Rev.* **29,** 239–259 (1999).

166. Sandom, C. J., Hughes, J. & Macdonald, D. W. Rewilding the scottish highlands: Do wild boar, sus scrofa, use a suitable foraging strategy to be effective ecosystem engineers? *Restor. Ecol.* **21,** 336–343 (2013).

167. Boklund, A., Goldbach, S. G., Uttenthal, Å. & Alban, L. Simulating the spread of classical swine fever virus between a hypothetical wild-boar population and domestic pig herds in Denmark. *Prev. Vet. Med.* **85,** 187–206 (2008).

168. Alban, L. *et al. Classical swine fever and wild boar in Denmark : A risk analysis*. *Risk Management* (2005).

169. Verpoest, S., Cay, A. B. & De Regge, N. Molecular characterization of Belgian pseudorabies virus isolates from domestic swine and wild boar. *Vet. Microbiol.* **172,** 72–77 (2014).

170. Fern??ndez, N., Kramer-Schadt, S. & Thulke, H. H. Viability and risk assessment in species restoration: Planning reintroductions for the wild boar, a potential disease reservoir. *Ecol. Soc.* **11,** (2006).

171. Tsachalidis, E. P. Reintroduction and hunting harvest of the wild boar (Sus scrofa Linnaeus, 1758) (Mammalia, Suidae) in the Peloponnesus, southern Greece. *J. Biol. Res.* **10,** 215–219 (2008).

172. CEH & JNCC. National Biodiversity Network. (2015). at <https://data.nbn.org.uk>

173. B�ttner, K. & Worel, G. Reintroduction of the europran wildcat in Bavaria, Germany. A project of the Bund Naturschutz in Bavaria. *Waldhygiene* **18,** 169–176 (1990).

174. Hartman, M. in *Iberian Lynx Ex-situ Conservation Seminar Series: Book of Proceedings* **_Proceedin,** 135–136 (2006).

175. Smith, D. & Convery, I. Application to Scottish Natural Heritage for the trial reintroduction of lynx to Scotland. 1–75 (2015).

176. Klar, N. *et al.* Between ecological theory and planning practice: (Re-) Connecting forest patches for the wildcat in Lower Saxony, Germany. *Landsc. Urban Plan.* **105,** 376–384 (2012).

177. Klar, N. *et al.* Habitat selection models for European wildcat conservation. *Biol. Conserv.* **141,** 308–319 (2008).

178. Lozano, J., Virgós, E., Malo, A. F., Huertas, D. L. & Casanovas, J. G. Importance of scrub-pastureland mosaics for wild-living cats occurrence in a Mediterranean area: Implications for the conservation of the wildcat (Felis silvestris). *Biodivers. Conserv.* **12,** 921–935 (2003).

179. Garrott, R. a *et al.* Generalizing wolf effects across the Greater Yellowstone Area: A cautionary note. *Wildl. Soc. Bull.* **33,** 1245–1255 (2005).

180. Beyer, H. L., Merrill, E. H., Varley, N. & Boyce, M. S. Willow on Yellowstone'S Northern Range: Evidence for a Trophic Cascade? *Ecol. Appl.* **17,** 1563–1571 (2007).

181. Kauffman, M. J. *et al.* Landscape heterogeneity shapes predation in a newly restored predator-prey system. *Ecol. Lett.* **10,** 690–700 (2007).

182. Kuijper, D. P. J. *et al.* Landscape of fear in Europe: Wolves affect spatial patterns of ungulate browsing in Bialowieza Primeval Forest, Poland. *Ecography (Cop.).* **36,** 1263–1275 (2013).

183. Beschta, R. L. & Ripple, W. J. Wolves, elk, and aspen in the winter range of Jasper National Park, Canada. *Can. J. For. Res.* **37,** 1873–1885 (2007).

184. Berger, K. M. Effects of a species-level trophic cascade on pronghorn fawn survival in Grand Teton National Park. *Proceedings of the 22nd biennial pronghorn workshop* 179 (2006).

185. Ripple, W. J. & Beschta, R. L. Wolves, elk, willows, and trophic cascades in the upper Gallatin Range of southwestern Montana, USA. *For. Ecol. Manage.* **200,** 161–181 (2004).

186. Gorman, M. L. Restoring ecological balance to the British mammal fauna. in *Mammal Review* **37,**

316–325 (2007).

187. Nilsen, E. B. *et al.* Wolf reintroduction to Scotland: public attitudes and consequences for red deer management. *Proc. Biol. Sci.* **274,** 995–1002 (2007).

188. Manning, A. D., Gordon, I. J. & Ripple, W. J. Restoring landscapes of fear with wolves in the Scottish Highlands. *Biol. Conserv.* **142,** 2314–2321 (2009).

189. Stohr, W. G. Trophic Cascades and Private Property: The Challenges of a Regulatory Balancing Act and Lessons the UK can Learn from the Reintroduction of the American Gray Wolf. *Univ. Balt. J. L. Dev.* **2,** (2012).

190. Sandom, C., Bull, J., Canney, S. & Macdonald, D. W. in *Fencing for Conservation: Restriction of Evolutionary Potential Or a Riposte to Threatening Processes?* 245–276 (2012). doi:10.1007/978-1-4614-0902-1_14

191. Ednarsson, M. Attitudes towards large carnivores and carnivore tourism among tourism entrepreneurs in Sweden. *Rev. Geogr. Alp.* **94,** 47–67 (2006).

192. Wilson, M. A. & Heberlein, T. A. The wolf, the tourist, and the recreational context: New opportunity or uncommon circumstance? *Hum. Dimens. Wildl.* **1,** 38–53 (1996).

193. Wallner, A. & Hunziker, M. The wolf controversy - interviews with experts on the social acceptance of the wolf in Switzerland. *For. Snow Landsc. Res.* **76,** 191–212 (2001).

194. Marshall, K. & Edwards-Jones, G. Reintroducing capercaillie (Tetrao urogallus) into southern Scotland: Identification of minimum viable populations at potential release sites. *Biodivers. Conserv.* **7,** 275–296 (1998).

195. Spittler, H. Reintroduction trials of capercaillie (Tetrao urogallus L) in Hochsauerland. *Z. Jagdwiss.* **40,** 185–199 (1994).

196. Holloway, C. W. & Jungius, H. Reintroduction of Certain Mammal and Bird Species into the Gran Paradiso National Park. *Zool.Anz., Leipzig* **191,** 1–44 (1973).

197. Salvi, A., Riols, C., Petit, P. & Moreau, G. New data on the common crane Grus grus in France. *Vogelwelt* **117,** 145–147 (1996).

198. Mathews, F. & Macdonald, D. W. The sustainability of the common crane (Grus grus) flock breeding in Norfolk: Insights from simulation modelling. *Biol. Conserv.* **100,** 323–333 (2001).

199. Zuberogoitia, I., Torres, J. J. & Martinez, J. A. Population reinforcement of Eagle Owl Bubo bubo in Biscay (Spain). *Ardeola* **50,** 237–244 (2003).

200. Radler, K. & Bergerhausen, W. ON THE LIFE HISTORY OF A REINTRODUCED POPULATION OF EAGLE OWLS (Bubo bubo). *Proc. Int. Symp. Raptor Reintroduction* 83–94 (1988).

201. Bergerhausen, W. Reintroduction of the European eagle owl Bubo b. bubo in the Federal Republic of Germany. *Int. Zoo Yearb.* **23,** 95–100 (1984).

202. Ishigaki, K. 100 Square Meters Forest Trust and restoration of extinct animals. *Bull. Shiretoko Museum* **26,** 25–27 (2005).

203. Ashbrook, K., Taylor, A., Jane, L., Carter, I. & Székely, T. Impacts of survival and reproductive success on the long-term population viability of reintroduced great bustards Otis tarda in the UK. *Oryx* 1–10 (2015). doi:10.1017/S0030605315000368

204. Osborne, P. E. Key issues in assessing the feasibility of reintroducing the great bustard Otis tarda to Britain. *Oryx* **39,** 22–29 (2005).

205. Burnside, R. J. *et al.* The UK great bustard Otis tarda reintroduction trial: a 5-year progress report. *Oryx* **46,** 112–121 (2011).

206. Dennis, R. & Dixon, H. The experimental reintroduction of Ospreys Pandion haliaetus from Scotland to England. *Vogelwelt* **122,** 147–154 (2001).

207. Monti, F. *et al.* The Osprey reintroduction in Central Italy: dispersal, survival and first breeding data. *Bird Study* **61,** 465–473 (2014).

208. Muriel, R., Ferrer, M., Casado, E. & Pérez Calabuig, C. First successful breeding of reintroduced ospreys pandion haliaetus in mainland Spain. *Ardeola* **57,** 175–180 (2010).

209. Wolff, W. J. The south-eastern North Sea: Losses of vertebrate fauna during the past 2000 years. *Biol. Conserv.* **95,** 209–217 (2000).

210. Olsson, O. & Rogers, D. J. Predicting the distribution of a suitable habitat for the white stork in Southern Sweden: Identifying priority areas for reintroduction and habitat restoration. *Anim. Conserv.* **12,** 62–70 (2009).

211. Olsson, O. Genetic origin and success of reintroduced white storks. *Conserv. Biol.* **21,** 1196–1206 (2007).

212. Schaub, M., Pradel, R. & Lebreton, J. D. Is the reintroduced white stork (Ciconia ciconia) population in Switzerland self-sustainable? *Biol. Conserv.* **119,** 105–114 (2004).

213. Galarza, A. & Garcia, I. Restocking white stork Ciconia ciconia (L., 1758) population in Biscay: reintroduction in the Urdaibai Biosphere Reserve. *Munibe* **60,** 191–200 (2012).

214. Green, R. E., Pienkowski, M. W. & Love, J. a. Long-term viability of the reintroduced population of the white-tailed eagle Haliaeetus albicilla in Scotland. *J. Appl. Ecol.* **33,** 357–368 (1996).

215. Tobajas, J., Fernandez-de-Simon, J., D??az-Ruiz, F., Villafuerte, R. & Ferreras, P. Functional responses to changes in rabbit abundance: is the eagle owl a generalist or a specialist predator? *European Journal of Wildlife Research* (2015). doi:10.1007/s10344-015-0976-7

216. Czajkowski, M., Giergiczny, M., Kronenberg, J. & Tryjanowski, P. The economic recreational value of a white stork nesting colony: Acase of 'stork village' in Poland. *Tour. Manag.* **40,** 352–360 (2014).

217. DFO. *Recovery Strategy for the Grey Whale (Eschrichtius robustus), Atlantic Population, in Canada*. *Atlantic* (2007). doi:978-0-662-46916-2

218. Bezold, J. & Peterson, D. L. Assessment of Lake Sturgeon Reintroduction in the Coosa River System, Georgia-Alabama. in *BALANCING FISHERIES MANAGEMENT AND WATER USES FOR IMPOUNDED RIVER SYSTEMS* **62,** 571–586 (2008).

219. Arlati, G., Grassi, A. & A, G. Restocking Acipenser naccarii in the Lombardy Region. *J. Appl. Ichthyol.* **15,** 298 (1999).

220. Prie, V. & Cochet, G. Restoring ecosystems functionalities: A proposal for reintroduction of the Atlantic Sturgeon Acipenser oxyrinchus Mitchill, 1815 to save Giant Pearl Mussel Margaritifera auricularia (Spengler, 1793) from extinction. *MalaCo* **6,** 270–277 (2010).

221. Navarro, L. M. & Pereira, H. M. in *Rewilding European Landscapes* 3–23 (2015). doi:10.1007/978-3-319-12039-3_1

222. May, A., Hall, J. & Pretty, J. Managed retreat in Essex: Rewilding the coast at Abbots Hall. *Ecos* **27,** 36–43 (2006).

223. Wubs, E. R. J., van der Putten, W. H., Bosch, M. & Bezemer, T. M. Soil inoculation steers restoration of terrestrial ecosystems. *Nat. Plants* **2,** 16107 (2016).

224. Scheper, J. *et al.* Museum specimens reveal loss of pollen host plants as key factor driving wild bee decline in The Netherlands. *Proc. Natl. Acad. Sci. U. S. A.* **111,** 17552–7 (2014).

225. Roulston, T. H. & Goodell, K. The role of resources and risks in regulating wild bee populations. *Annu. Rev. Entomol.* **56,** 293–312 (2011).

226. Bumblebee Conservation Trust. *Grassland restoration and creation for bumblebees*. at <http://bumblebeeconservation.org/get-involved/managing-your-land/grassland/>

227. Devries, P., Fetherston, K. L., Vitale, A. & Madsen, S. Emulating Riverine Landscape Controls of Beaver in Stream Restoration Emulating Riverine Landscape Controls of Beaver in Stream Restoration. *Fisheries* **37,** 246–255 (2012).

228. Fenton, J. H. C. Is rewilding destroying the remaining naturalness of the Scottish Highlands ? 1–6 (2015).

229. Chapron, G. *et al.* Recovery of large carnivores in Europe's modern human-dominated landscapes. *Science (80-.).* **346,** 1517–1519 (2014).

230. Taylor, P. Towards a wildland strategy. *Ecos* **25,** 1–3 (2004).

231. National Species Reintroduction Forum. *Best practice guidelines for conservation translocations in Scotland*. (2014).

232. Griffiths, C. J., Zu??l, N., Jones, C. G., Ahamud, Z. & Harris, S. Assessing the potential to restore historic grazing ecosystems with tortoise ecological replacements. *Conserv. Biol.* **27,** 690–700 (2013).

233. Hansen, D. M., Kaiser, C. N. & Müller, C. B. Seed dispersal and establishment of endangered plants on oceanic islands: The Janzen-Connell model, and the use of ecological analogues. *PLoS One* **3,** (2008).

234. Hanna, C., Foote, D. & Kremen, C. Invasive species management restores a plant-pollinator mutualism in Hawaii. *J. Appl. Ecol.* **50,** 147–155 (2013).

235. Aslan, C. E., Aslan, A., Croll, D., Tershy, B. & Zavaleta, E. Building taxon substitution guidelines on a biological control foundation. *Restor. Ecol.* **22,** 437–441 (2014).

236. Brooker, R., Britton, A., Gimona, A., Lennon, J. & Littlewood, N. *Literature review : species translocations as a tool for biodiversity conservation during climate change*. *Scottish Natural Heritage Commissioned Report No.440* (2011).

237. Lunt, I. D. *et al.* Using assisted colonisation to conserve biodiversity and restore ecosystem function under climate change. *Biological Conservation* **157,** 172–177 (2013).

238. Seddon, P. J., Moehrenschlager, A. & Ewen, J. Reintroducing resurrected species: selecting DeExtinction candidates. *Trends Ecol. Evol.* (2014).

239. Seddon, P. J., Griffiths, C. J., Soorae, P. S. & Armstrong, D. P. Reversing defaunation: Restoring species in a changing world. *Science (80-.).* **345,** 406–412 (2014).

240. Heard, M. J. De-extinction: raising the dead and a number of important questions. *Front. Biogeogr.* **6,** (2014).

241. Sandler, R. The ethics of reviving long extinct species. *Conserv. Biol.* **28,** 354–360 (2014).

242. Minteer, B. Is it right to reverse extinction? *Nature* **509,** 261 (2014).

243. Fletcher, A. L. *Mendel's Ark: Biotechnology and the future of extinction*. *Mendel's Ark: Biotechnology and the Future of Extinction* (2014). doi:10.1007/978-94-017-9121-2

244. Kupferschmidt, K. Can Cloning Revive Spain's Extinct Mountain Goat? *Science (80-.).* **344,** 137–138 (2014).

245. Jones, K. E. From dinosaurs to dodos: who and what should we de-extinct. *Front. Biogeogr.* **6,** 217–220 (2014).

246. Miller, S. M., Harper, C. K., Bloomer, P., Hofmeyr, J. & Funston, P. J. Fenced and Fragmented: Conservation Value of Managed Metapopulations. *PLoS One* **10,** e0144605 (2015).

247. Natural England. Biodiversity 2020 : Frequently Asked Questions (July 2013). 1–9 (2016). at <http://publications.naturalengland.org.uk/publication/4985334970449920>

248. Josh Donlan, C. *et al.* Pleistocene rewilding: an optimistic agenda for twenty-first century conservation. *Am. Nat.* **168,** 660–681 (2006).

249. Merckx, T. in *Rewilding European Landscapes* 107–125 (2015). doi:10.1007/978-3-319-12039-3_6

250. Nummi, P. & Holopainen, S. Whole-community facilitation by beaver: Ecosystem engineer increases waterbird diversity. *Aquat. Conserv. Mar. Freshw. Ecosyst.* **24,** 623–633 (2014).

251. Dalbeck, L., Janssen, J. & Luise Völsgen, S. Beavers (Castor fiber) increase habitat availability, heterogeneity and connectivity for common frogs (Rana temporaria). *Amphibia-Reptilia* **35,** 321–329 (2014).

252. Harthun, M. The influence of the European beaver (Castor fiber albicus) on the biodiversity (Odonata, Mollusca, Trichoptera, Ephemeroptera, Diptera) of brooks in Hesse (Germany). *Limnologica* **29,** 449–464 (1999).

253. Kemp, P. S., Worthington, T. A., Langford, T. E. L., Tree, A. R. J. & Gaywood, M. J. Qualitative and quantitative effects of reintroduced beavers on stream fish. *Fish Fish.* **13,** 158–181 (2012).

254. Gibson, P. P., Olden, J. D. & O'Neill, M. W. Beaver dams shift desert fish assemblages toward dominance by non-native species (Verde River, Arizona, USA). *Ecology of Freshwater Fish* (2014). doi:10.1111/eff.12150

255. Cerqueira, Y. *et al.* in *Rewilding European Landscapes* 47–64 (2015).

256. Alonso, I., Weston, K., Gregg, R. & Morecroft, M. *Carbon storage by habitat: Review of the evidence of the impacts of management decisions and condition of carbon stores and sources*. **Research R,** (2012).

257. Iacob, O., Rowan, J. S., Brown, I. & Ellis, C. Evaluating wider benefits of natural flood management strategies: an ecosystem-based adaptation perspective. *Hydrol. Res.* **45,** 774–787 (2014).

258. Natural Capital Committee. *The State of Natural Capital: Third report*. (2015).

259. Wohl, E. Landscape-scale carbon storage associated with beaver dams. *Geophys. Res. Lett.* **40,** 3631–3636 (2013).

260. Lazar, J. G., Addy, K., Welsh, M. K., Gold, A. J. & Groffman, P. M. Resurgent Beaver Ponds in the Northeastern United States: Implications for Greenhouse Gas Emissions. *J. Environ. Qual.* **43,** 1844–1852 (2014).

261. Bullock, J. M., Aronson, J., Newton, A. C., Pywell, R. F. & Rey-Benayas, J. M. Restoration of ecosystem services and biodiversity: Conflicts and opportunities. *Trends Ecol. Evol.* **26,** 541–549 (2011).

262. Jones, H. P., Hole, D. G. & Zavaleta, E. S. Harnessing nature to help people adapt to climate change. *Nat. Clim. Chang.* **2,** 504–509 (2012).

263. Vega-Leinert, A., Nicholls, R. J., de la Vega-Leinert, A. C. & Nicholls, R. J. Potential implications of sea-level rise for Great Britain. *J. Coast. Res.* **24,** 342–357 (2008).

264. Wigand, C. *et al.* Outline of A New Approach to Evaluate Ecological Integrity of Salt Marshes. *Hum. Ecol. Risk Assess.* **7,** 1541–1554 (2001).

265. Tempest, J. A., Harvey, G. L. & Spencer, K. L. Modified sediments and subsurface hydrology in natural and recreated salt marshes and implications for delivery of ecosystem services. *Hydrol. Process.* **29,** 2346–2357 (2015).

266. Marshall, M. R. *et al.* The impact of rural land management changes on soil hydraulic properties and runoff processes: Results from experimental plots in upland UK. *Hydrol. Process.* **28,** 2617–2629 (2014).

267. Bulygina, N., McIntyre, N. & Wheater, H. A comparison of rainfall-runoff modelling approaches for estimating impacts of rural land management on flood flows. *Hydrol. Res.* **44,** 467 (2013).

268. Nyssen, J., Pontzeele, J. & Billi, P. Effect of beaver dams on the hydrology of small mountain streams: Example from the Chevral in the Ourthe Orientale basin, Ardennes, Belgium. *J. Hydrol.* **402,** 92–102 (2011).

269. Lisle, S. The use and potential of flow devices in beaver management. *Lutra* **46,** 211–216 (2003).

270. Clements, H. S., Baum, J. & Cumming, G. S. Money and motives: An organizational ecology perspective on private land conservation. *Biol. Conserv.* **197,** 108–115 (2016).

271. The Wildlife Trust. Nature and Wellbeing Act. (2015). at <http://www.wildlifetrusts.org/NWA>

272. Sport & Recreation Alliance. *Reconomics*. (2014). at <http://www.sportandrecreation.org.uk/policy/research/reconomics>

273. Barrett, K. R. Ecological engineering in water resources: The benefits of collaborating with nature. *Water Int.* **24,** 182–188 (1999).

274. Peh, K. S. H. *et al.* Benefits and costs of ecological restoration: Rapid assessment of changing ecosystem service values at a U.K. wetland. *Ecol. Evol.* **4,** 3875–3886 (2014).

275. Törnblom, J., Anglestam, P., Hartman, G., Henrikson, L. & Göran. Toward a Research Agenda for Water Policy Implementation: Knowledge about Beaver (Castor fiber) as a Tool for Water

Management with a Catchment Perspective. *Balt. For.* **17,** 154–161 (2011).

276. Beschta, R. L. *et al.* Adapting to climate change on Western public lands: addressing the ecological effects of domestic, wild, and feral ungulates. *Environ. Manage.* **51,** 474–491 (2012).

277. Graves, A. *et al. The total costs of soils degradation in England and Wales*. (2015).

278. Hood, G. A. & Larson, D. G. Ecological engineering and aquatic connectivity: A new perspective from beaver-modified wetlands. *Freshw. Biol.* **60,** 198–208 (2015).

279. Rutherford, M. C., Powrie, L. W. & Husted, L. B. Herbivore-driven land degradation: Consequences for plant diversity and soil in arid subtropical thicket in South-Eastern Africa. *L. Degrad. Dev.* **25,** 541–553 (2014).

280. Fairchild, G. W. & Velinsky, D. J. Effects of small ponds on stream water chemistry. *Lake Reserv. Manag.* **22,** 321–330 (2006).

281. Macdonald, D. W., Tattersall, F. H., Brown, E. D. & Balharry, D. Reintroducing the European Beaver to Britain: nostalgic meddling or restoring biodiversity? *Mamm. Rev.* **25,** 161–200 (1995).

282. Marquiss, M. *et al.* The impact of white-tailed eagles on sheep farming on Mull: final report. *impact white-tailed eagles sheep farming Mull Final report.* 1–46 (2004). at <<Go to ISI>://ZOOR14012071637>

283. Odden, J., Nilsen, E. B. & Linnell, J. D. C. Density of wild prey modulates lynx kill rates on free-ranging domestic sheep. *PLoS One* **8,** (2013).

284. Fritzemeier, J. *et al.* Epidemiology of classical swine fever in Germany in the 1990s. in *Veterinary Microbiology* **77,** 29–41 (2000).

285. Goodman, G. The Scottish Beaver Trial : Veterinary Monitoring of the Knapdale Beaver Population 2009-2014. (2014).

286. Ostfeld, R. S. & Holt, R. D. Are predators good for your health? Evaluating evidence for top-down regulations of zoonotic disease reservoirs. *Front Ecol Env.* **2,** 13–20 (2004).