One Hundred Priority Questions for Landscape Restoration in Europe

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Abstract

We present the results of a process to attempt to identify 100 questions that, if answered, would make a substantial difference to terrestrial and marine landscape restoration in Europe. Representatives from a wide range of European governmental and non-governmental conservation organizations, universities, independent ecologists and land managers compiled 677 questions relating to all aspects of European landscape restoration for nature and people. The questions were shortlisted by an email vote, followed by a two-day workshop, to produce the final list of 100 questions. Many of the final questions evolved through a process of modification and combination as the workshop progressed. The questions are divided into eight sections: conservation of biodiversity; connectivity, migration and translocations; delivering and evaluating restoration; natural processes; ecosystem services; social and cultural aspects of restoration; policy and governance; and economics. We anticipate that these questions will help identify new directions for researchers and policy-makers and assist funders and programme managers in allocating funds and planning projects, resulting in improved understanding and implementation of landscape-scale ecological restoration in Europe.

Keywords: natural processes, landscape-scale, priority setting, rewilding, ecological restoration, biodiversity

Introduction

Ecological restoration, defined as the process of assisting or allowing the recovery of an ecosystem that has been degraded, damaged, or destroyed (SER 2004), has been the focus of increasing recent political and research attention. Restoration is of particular importance in densely-occupied and ecologically-transformed Europe, in order to retain and enhance the capacity of ecosystems to provide for the present and future needs of millions of people, enable the function of natural processes, and conserve threatened biodiversity. The creation of large restored areas has been given heightened urgency by recent international policy targets (Aronson & Alexander 2013). The Convention on Biological Diversity identified restoration as key to delivering essential ecosystem services (Aichi Biodiversity Target 14), and has a global target of restoring at least 15% of degraded ecosystems by 2020 (Aichi Target 15; CBD 2014). This has been adopted as Target 2 of the EU's 2011-2020 Biodiversity Strategy (EU 2011), which is of especial relevance to this paper. However, the mid-term review of the EU's progress towards meeting this target reported that there had been 'progress but at an insufficient rate', with some restoration activities having occurred, but without a halt in the degradation of ecosystems and services (European Commission 2015). Other global initiatives calling for increased attention to landscape restoration include the Global Partnership for Forest Landscape Restoration and its Bonn Challenge to bring 150 million hectares of the world's deforested and degraded land into restoration by 2020, and 350 million hectares by 2030 (Suding et al. 2015). The impending deadline for these targets has created impetus for moving forward with large-scale restoration programmes across Europe, but their success will depend on our capacity to implement them effectively.

As well as policy drivers, recent progress in a range of relevant areas have provided additional momentum to the landscape restoration movement. Ecological and technological advances (Perring et al. 2015), new dynamics in green and sustainable finance (FAO & UNCCD 2015), and approaches incorporating the commodity supply chain into sustainable landscapes all have implications for restoration. Concepts of restoration are also evolving rapidly; these include the desired target state for restoration projects (whether aiming for a historic baseline, or a novel enhanced system), the approaches employed and level of management intensity needed, and how to incorporate human impacts on landscapes into restoration programmes (Corlett 2016, Bowman et al. 2017).

Landscapes are large, heterogeneous and multifunctional environments that provide diverse services and values to multiple stakeholders. Landscape restoration therefore refers to restoration of biodiversity and natural processes within degraded lands and seas on a scale that may vary from a few square kilometres to ecological corridors that traverse continents. Such restoration projects are typically complex, covering a mosaic of habitats and species' ranges, and affecting a wide range of people in many different ways. They may also cross political boundaries and involve a large number of private and public landowners working in often complex partnerships. Consequently, restoration success at such scales is commonly dependent upon a wide range of interacting cultural, social, political and economic factors, in addition to ecological considerations. This is particularly well illustrated in the Mediterranean Basin where different legal frameworks exist between EU and non-EU countries, and information availability and cultural attitudes have variously assisted or constrained the development of landscape restoration projects (Nunes et al. 2016).

Given the current significance of landscape restoration in Europe, and the complexity of the ecological and socio-economic factors involved in large-scale initiatives, it seems valuable to take stock of relevant information needs. Although there is much individuality in landscapes and restoration schemes, there are many knowledge gaps with wider relevance which need to be tackled if restoration targets are to be achieved in the most effective manner. This exercise aimed to identify these knowledge gaps, in order to encourage researchers, funders and programme managers to focus funding and research energy towards addressing these gaps. We also hoped to contribute towards improving the integration of science and policy (Koetz et al. 2012), by seeking input from experts in both areas, to identify questions that satisfied both scientific rigour and policy relevance.

In order to identify 100 questions that, if answered, would make a substantial difference to landscape restoration in Europe, we brought together 37 practitioners, policy-makers, academics, landowners and managers from a range of backgrounds across Europe. The criteria for identifying and prioritising these questions specifically stipulated that answering them should make a demonstrable difference to our ability to carry out landscape restoration in Europe. We hope that by specifying and publicising these questions, identified by a diverse set of participants using a structured and transparent process, we are providing an agenda and justified rigorous basis for those involved in restoration projects to undertake field experiments, literature reviews or meta-analyse to answer one or more of these priority questions. Our aim in presenting these results is to stimulate debate and, more importantly, to inspire research that will contribute towards enabling European countries to meet the Aichi Biodiversity Targets and related policy commitments.

The scope of this exercise is defined as geographical Europe, and so excludes European territories outside this area. Inevitably several questions, particularly those relating to policy, refer specifically to the European Union, but most questions are relevant to the whole of geographical Europe. We also encompass all ecosystems and biotopes; unless specified, all questions relate to restoration in both terrestrial and marine ecosystems, and our use of the word 'landscape' does not exclude coastal and marine seascapes, but rather reflects the large spatial scale of the project.

In Europe, as in many other parts of the world, there is a tension between restoring the sorts of environments and species associated with historic land management, and more laissez faire, non-interventionist approaches, which aim to restore natural ecosystem processes with low levels of management. The concept of rewilding, with its increased emphasis on natural physical and biological processes over interventionist management, has received much recent attention, debating both the applicability of the approach, and how, where and to what extent it should be pursued

(Pereira & Navarro 2015, Corlett 2016, Svenning et al. 2016). Many of the issues raised by the rewilding debate, such as questions about spatial and temporal scales or how to restore natural processes and enhance connectivity, have relevance for other forms of landscape restoration. However, the breadth and variety of meaning attached to the term (Jørgensen 2015, Lorimer et al. 2015) creates considerable potential for confusion (Carver 2016). Therefore, we have restricted the use of the word rewilding to questions where it is directly relevant, and have been specific about mechanisms and interventions (e.g. specifying the reintroduction of large carnivores or herbivores) in order to avoid ambiguity.

Methods

In order to identify the most important questions in European landscape restoration we employed an iterative process of voting, discussion and refining questions. We followed a previously used method (Sutherland et al. 2006) to ensure a rigorous, democratic and transparent process (Figure 1, Sutherland et al. 2013).

The questions identified during this process will inevitably reflect the interests and experiences of the participants. Participants were therefore selected using a structured process, which aimed to cover a wide range of disciplines, ecosystems and habitats, as well as representing a variety of organisational backgrounds (please see author list for participant affiliations) and geographic regions (Figure 2). We thus aimed to maximise the range of questions submitted, as well as the expertise and experience present during discussion and synthesis of the questions, as far as possible within the constraints of the meeting format and budget. All participants are authors of this paper.

Participants were asked to submit between 5 and 25 questions to the exercise, and were encouraged to consult widely in identifying these, resulting in the active participation of 893 people and an initial total of 677 questions. Participants were asked to identify useful, answerable questions that could feasibly be tackled by a research team with a small number of grants, and to avoid broad, general questions. In addition, questions had to meet the criteria that they (i) be answerable through a realistic research design; (ii) have a factual answer that does not depend on value judgments; (iii) address important gaps in knowledge; (iv) are at an appropriate spatial and temporal scale and scope; and (v) fall within the scope of the exercise.

The 677 submitted questions were initially assigned to 12 broad themes, reflecting subject areas in landscape scale restoration. Participants were then asked to vote anonymously by email for the 5-13 most important questions in those thematic sections where they felt competent to comment, with the number of votes allocated to each theme proportional to the number of questions in the theme. Participants were also given the opportunity to suggest questions that could be re-worded or combined. The results of the voting, plus comments made by participants, were circulated to all participants before the meeting.

A two-day workshop was held in Cambridge, UK in November 2017. In the first stage, the participants were divided into 12 working groups, each of which considered one theme, to identify duplicate questions, those that had already been answered, and those that could be improved by further rephrasing. The working group chairs moderated a discussion in which the number of questions was reduced by approximately two thirds, to produce a list to be carried forward to the second stage (Figure 1). Each group divided the retained questions into a specified number (proportional to the number of questions in the theme) of ‘bronze’, ‘silver’ and ‘gold’ questions, ranked in order of increasing importance. Chairs were asked to ensure the process was democratic with all views heard. Where there was no clear consensus, decisions were made using voting by a show of hands.

The second stage of the workshop consisted of two sets of two parallel sessions, each of which refined the questions from three of the initial thematic working groups, using a similar approach to the first stage. The number of questions was reduced by approximately half, and new gold, silver and bronze categories were created from the retained questions, based on group discussion and voting. In the third and final session, the gold questions carried forward from the second stage were examined again; questions which, after further discussion, were thought not to be of the highest importance were demoted to silver. Participants were then asked to identify whether any of the questions classified as bronze should be moved into silver. The final round of voting chose the most important silver questions to join the gold questions, creating the final list of 100.

This voting process was designed so that at each stage the previous decisions were influential but could also be overruled. It also provided the opportunity to merge similar questions that derived from different initial themes. Furthermore, questions from different groups were compared against each other to ensure that they were of equivalent importance and to reduce possible biases, for example due to a disproportionate number of questions initially suggested in one subject area.

As described above, the most important caveat relating to the questions presented in this paper is that they are likely to be influenced by the interests and expertise of the participants. Efforts were made to solicit questions and select attendees from across the many aspects of landscape restoration, but some biases are inevitable. For logistical and financial reasons the majority of participants were from the UK, and hence there is a geographical bias, although most had experience of working in several bioregions of Europe (Figure 2). We invited participants with experience in a range of ecosystems (wetlands, agriculture, grassland, forests, marine) and tried to maximise the number of people who had experience of planning, implementing and monitoring European landscape restoration programmes. Most participants worked in non-governmental organisations (17) or academic institutions (16), with others based in governmental or inter-governmental organisations (5) or the private sector (4) (some individuals were associated with more than one organisation). The majority of participants were trained as biological scientists, and the group consisted of 28 men and 9 women.

The initial division of questions into themes may also have limited lateral thinking, and it was not clear where all questions should best be placed; the successive merging of themes was designed to address this issue. There was also a tendency to pose and, at least initially, prioritise broad questions rather than the more answerable, focussed questions the exercise specified. It was sometimes difficult to compare the importance of broad, general questions with those that referred to a specific issue or ecosystem. Our aim was to identify those that fell in the middle, and could feasibly be answered by a research programme but also had significance beyond a single system. Below we present the final 100 questions, split into eight broad subject areas; questions are grouped together in similar themes, and the order does not reflect rank or importance.

The questions

Conservation of biodiversity

Questions posed in this section examine both how landscapes can be restored to increase species' abundances, and the functional role of species in enhancing ecosystems and restoring habitats. In recent years, the focus of conservation has shifted from single species and individual reserves to the interaction of species, habitats and natural processes with the surrounding landscape, recognising the collective contribution of sites within a landscape to the conservation of species and the resilience of ecosystems (Adams et al. 2016, Donaldson et al. 2017). Several questions in this section ask how to better understand where landscape restoration might be most influential, and how to identify sites that are most likely to contribute to long-term conservation goals within a landscape, such as climate change refugia (Suggitt et al. 2014). Questions also reflect that restoration of high-nature value sites within a landscape may depend on adopting innovative and novel approaches (Perring et al. 2013, 2015). These include the use of species with important trophic or habitat engineering capabilities (Jones et al. 1994, Manning et al. 2015), and the identification of opportunities for novel ecosystems, for example as part of marine renewable energy developments (Callaway et al. 2017). The questions selected also reflect the importance of understanding how and when to reintroduce species to an area and the potential use of functional traits in developing acceptable outcomes (Frainer et al. 2017; see also next section).

1. How can landscape restoration enhance the abundances of declining species at large scales?
2. Where are Europe's most important climatic refugia in which endemic species are most likely to survive climate change, and what restoration actions do these sites require?
3. Which landscapes are the highest restoration priorities for the recovery of species of European Conservation Concern?
4. Which are the keystone species that can help deliver landscape restoration in different ecological systems?
5. How can we measure when a reintroduced species is achieving its expected ecological function?
6. What roles can non-native species play in landscape restoration?
7. How might genetic modification of wild organisms assist in restoring biodiversity and ecosystems, and how should we assess risks and public acceptability?
8. Under what circumstances can novel biological communities or ecological systems restore ecological processes and have positive biodiversity outcomes?
9. What will be the ecosystem, biodiversity and social consequences if landscape conservation projects in Europe seek to restore the ecological surrogates of extinct megafauna?

Connectivity, migration and translocations

The ability of plants and animals to move between patches of habitat is likely to enhance the resilience of populations, particularly under changing environmental conditions. Connectivity and the permeability of landscapes are therefore key considerations in large-scale restoration, which is likely to include patches of more and less suitable habitat for different species (Heller & Zavaleta 2009). This is especially evident in the heavily modified landscapes of Western Europe, where many high-value conservation sites are now surrounded by a matrix that has become increasingly hostile for many species (e.g. Hayhow et al. 2016). As a consequence, there has been increasing emphasis on the development of ecological networks (Opdam et al. 2006, Boitani et al. 2007) and the enhancement of habitat connectivity. However, the roles of different types of connectivity have been the subject of considerable debate amongst conservation scientists (Taylor et al. 2006), and several of the questions below relate to species' ability to move across landscapes and seascapes. Further questions ask how and where connectivity should be improved, and what knowledge is needed to achieve this, as well as asking how restoration of large-scale natural processes and connectivity may facilitate the passage of non-native species or pathogens through the landscape (With 2002). In some cases it may not be possible to 'reconnect' landscapes and remnant population fragments adequately, and there may be a need to consider translocating species as an additional, complementary approach.

10. Which species and habitats, including those that are human-modified, are most at risk from lack of connectivity, and which will benefit most from landscape-scale habitat networks and corridors?
11. What research is needed in order to develop guidance on the most ecologically- and cost-effective types of habitat corridors and stepping stones for different habitat communities or species assemblages?

12. How do we most effectively identify potential 'pinch points', where the restoration of landscape connectivity would most efficiently facilitate the redistribution of species under climate change?
13. Which changes in farming landscapes will make the biggest contribution to increasing the permeability of the lowlands to species?
14. Which are the critical landscape components within urban landscapes that are likely to maximise functional connectivity and resources for biodiversity?
15. What evidence do we have that connectivity across large areas is useful for restoring marine
16. biodiversity?
17. What are the risks to biodiversity from the spread of non-native, invasive species in restored ecosystems and landscapes, and what are the drivers and solutions?
18. What opportunities are there to restore rare and localised species outside the environments they currently occupy?
19. Under what circumstances will species colonise restored habitats and when do we need to translocate them?

Delivering and evaluating restoration

Delivering restoration at a landscape scale requires consideration of how to establish new habitats, enhance biodiversity and increase the complexity and dynamism of systems (Perring et al. 2015). Questions in this section ask how we can manage and evaluate these changes, and what are the shifts in approach that will be required to move from conventional species- and habitat-based conservation to restoration of a much broader range of natural processes at larger spatial and temporal scales (Hiers et al. 2012, Hughes et al. 2016). Several questions highlight the importance of a wider understanding of the mechanisms that restore dynamic natural processes, in particular soil function, in terms of its structure, biota and process rates. Other questions involve expanding the landscape restoration vision to include areas beyond a project that will continue to exert both positive and negative influence over it. Restoring marine systems presents its own challenges, both in terms of the threats faced (such as ocean acidification), the scale of the habitat, and the practical difficulties that can be involved in restoration and monitoring activities. These are compounded by a lack of knowledge of natural processes and the mechanisms required to restore them in marine systems, particularly the deep sea. There are also uncertainties around the potential of new technologies, such as remote sensing, drones, eDNA and mobile apps, to improve both management and monitoring (Deiner et al. 2017, Reif & Theel 2017). Applying these technologies to citizen science could open up opportunities for wider monitoring and natural resource management through volunteers, leading to broader ownership and understanding (McKinley et al. 2017, Bela et al. 2016). In addition to understanding the ecological complexities, we pose several questions asking how best to provide the necessary training and knowledge to individuals responsible for implementation, in order to deliver effective restoration.

20. How can emerging technologies deliver more effective landscape restoration?
21. How can emerging technologies be used to monitor landscape restoration more effectively?
22. How can landscape restoration improve soil quality and ecological function, and how much time is needed to detect changes?
23. Under which circumstances does restoration of soil, including manipulating the biota (bacterial and fungal community and macrofauna), enhance restoration?
24. Which restoration strategies effectively reduce high intensity fires by enhancing resilience to fire, thereby conserving biodiversity?
25. Which restoration techniques and approaches are suitable for restoring remnant habitats in landscapes dominated by agriculture?

26. Under what circumstances do chemical pollutants (fertilisers, pesticides, aerial deposition) compromise landscape restoration?
27. How does the surrounding landscape affect restoration outcomes and how does this vary with the scale of the restoration?
28. How can we restore marine ecosystems in the face of ocean acidification and warming?
29. Which management actions are most effective in restoring deep sea benthic habitats?
30. How might the principles of terrestrial restoration be applied to marine ecosystems?
31. What are the most appropriate temporal and spatial baselines for marine ecosystems?
32. What are the most suitable approaches for defining and measuring success, while allowing for uncertain and dynamic outcomes in landscape restoration?
33. How can we ensure that restoration practitioners have the knowledge to correctly specify appropriate planting stock and ensure that there is sufficient availability of such stock for restoration?
34. What are the best approaches to deliver the appropriate knowledge and training to those delivering landscape restoration at all levels?
35. What are the lessons learned and the knowledge transfer needs concerning soil restoration from across European landscapes and disciplines?

Natural processes

The questions chosen in this section relate to how to effectively restore biotic and abiotic processes, at a range of temporal and spatial scales, to create resilient functional ecosystems. Some processes, such as decomposition of organic matter, often occur at very small scales but take place across many parts of a landscape, providing cumulative restoration benefits. Others, such as river flooding and grazing and browsing by large populations of herbivores, operate at larger spatial scales. These larger-scale processes are of particular interest to landscape restoration projects and are often associated with the physical dynamism of ecosystems such as rivers, wetlands and coasts, or the biological dynamism associated with 'ecosystem engineers' (Jones et al. 1994, Manning et al. 2015) and seasonal migration of species. Several practical considerations relating to the restoration of these processes are addressed by questions in this section. Firstly, the scale and rate at which natural processes should be initiated in landscape-scale restoration are conceptually hard to determine (Willis & Birks 2006). Natural disturbance events such as storms, fires and floods are vital for the renewal of many ecosystems, but in practice the scales at which their benefits can be derived are constrained by human factors such as land use, infrastructure, and water extraction and management (Hughes et al. 2005). Secondly, the impacts of large-scale natural processes on habitat formation and heterogeneity, species assemblages, and ecosystem functioning and services are hard to predict, and change with time and space. Indeed, these essentially unpredictable and episodic processes potentially offer important lessons for restoration. Understanding the role of geo- and hydromorphological processes in shaping these relationships is another essential part of the restoration journey (Riquier et al. 2015).

36. What are the most promising restoration opportunities that might be derived from the restoration of geo- and hydromorphological processes?
37. Which attributes of landscapes increase resilience to climate change, and how can this knowledge be used to inform restoration priorities?
38. What are the impacts of, and potential opportunities associated with, episodic or extreme events on landscape restoration outcomes?
39. How should the location of restoration activities in the landscape take into account the major drivers of change, such as fire?
40. How can ecosystem management be designed to better emulate natural processes?
41. How will the increasing beaver populations across Europe, and their associated impacts on flow regimes, water quality and biodiversity, affect river catchment restoration?

42. How do different restoration outcomes vary with spatial scale?
43. Which factors affect the trajectory of change of biodiversity and ecosystem functions and services during restoration?
44. How do environmental gradients and heterogeneity influence biodiversity recovery in ecological restoration?
45. How important are the restoration and maintenance of dynamic transitional habitats at a landscape scale for restoring biodiversity?
46. How do we overcome barriers to restoration of scavenger and decomposer communities?
47. Which types of landscape restoration are most sensitive to human disturbance and how should we decide when to maintain restored areas free of human disturbance?
48. What is the evidence that rewilding, involving large-scale non-intervention management, has delivered ecological benefits?
49. In which cases can landscape restoration be pursued simply by non-intervention?

Ecosystem services

Ecosystem restoration can help enhance the direct and indirect benefits that people derive from nature, such as the improved carbon storage and climate regulation resulting from the restoration of peatlands (Bonn et al. 2016) or the increased marine fishery productivity that may result from seafloor restoration (Seaman 2007). Thus, the Convention on Biological Diversity specifies the need to consider ecosystem services in its strategic goals, with Aichi Target 15 emphasising the prioritisation of restoration of ecosystems that contribute to climate change mitigation and adaptation (CBD 2014). Overall, the ecosystem service concept can serve as a tool to understand both the costs of land degradation and the benefits from restoration to different beneficiaries across society (Guerry et al. 2015), thus providing important additional arguments for restoration efforts and engaging a wider range of sectors. Questions posed in this area mainly relate to how we can improve our understanding of the ecosystem benefits provided by restoration, and how efforts can be prioritised to maximise these. For strategic planning, a good understanding of the likely ecosystem services outcomes of different restoration management approaches and their synergies and trade-offs with biodiversity goals (e.g. Thomas et al. 2013) is needed, and several questions call for further research into these issues (Bullock et al. 2011). Scenarios and modelling can help to assess and prioritise the benefits that landscape restoration could help to deliver, both now and in the future (Rieb et al. 2017), and in particular the changing demands for ecosystem services that may occur under climate change.

50. Which landscape restoration approaches have the biggest overall benefits for the provision of ecosystem services and which ecosystem services would be enhanced?
51. Which natural capital changes would result from achieving Aichi Biodiversity Target 15 in Europe, by restoring 15% of degraded landscapes?
52. Which types of landscapes would deliver the greatest benefits for both biodiversity and ecosystem services if restored, and where are they?
53. What are the synergies and trade-offs between ecosystem services and biodiversity conservation goals during landscape restoration, and how can they be reconciled?
54. How can we map the potential benefits of ecological restoration for ecosystem services at an operational scale, relevant for local decisions?
55. Which restoration practices can contribute to the improved provision of ecosystem services and biodiversity in agricultural landscapes under climate change?
56. Where are the priority areas and approaches for landscape restoration projects in order to optimise water management and risk today and in response to a changing climate?
57. Where are the priority areas in which restoration of natural wetlands can contribute to climate change mitigation and adaptation by buffering extreme wet or dry periods?

58. Which people and communities are most vulnerable to climate change and how can landscape-scale ecosystem restoration assist them?
59. How can we plan restoration programmes to help meet expected future ecosystem services demand?

Social and cultural aspects of restoration

The development of landscape-scale conservation and restoration projects has significant social and economic implications (Adams et al. 2014). The idea of “landscape” has emerged with different meanings in different countries across Europe (Olwig 1996), and historically rural landscapes have been taken to reflect aspects of national identity (Lekan 2004). People often develop strong personal and emotional attachments to particular ideas of landscape, for example through long-term involvement as land managers (e.g. in farming or forestry practices), regular use (e.g. hunting, fishing, dog walking or bird watching) or occasional visits (e.g. holidays) (Cullen-Unsworth et al. 2014). Such values do not necessarily reflect value for biodiversity, and several questions in this area relate to the reconciliation of potential differences in priorities of restoration for social and cultural features compared to for ecology or biodiversity. Successful restoration projects depend on the effective, collaborative engagement of local people from an early stage, and other questions ask how this can be effectively fostered, as well as how to deal with conflict when this arises.

Landscape restoration can bring positive social benefits (e.g. employment or the return of valued wild species) and potentially contribute to improvements in human health and wellbeing (Aronson et al. 2016), and several questions highlight the need for an improved understanding of these effects. Restoration can also bring significant costs, such as loss of livestock from predation or changes in access or land use. It is therefore vital that the benefits of restoration are fairly distributed and costs adequately mitigated. This is reflected in questions asking how attitudes may positively or negatively affect landscape restoration projects, and highlighting the importance of knowledge accessibility as a way to facilitate nature-culture interaction.

60. How do we align social and ecological aspirations for landscape restoration?
61. How do we reconcile the restoration of cultural and natural features in European landscapes where trade-offs have to be made?
62. To what extent do cultural attitudes towards what constitutes "natural landscapes" impact on the acceptability of ecological restoration?
63. Which social, cultural and historical factors most strongly shape attitudes and attachments to landscapes and their restoration?
64. To what extent do cultural values towards iconic species limit or promote potential landscape restoration projects?
65. To what extent is the restoration of damaged marine ecosystems limited by a lack of public awareness of their status and prevailing attitudes to these habitats?
66. To what extent do existing conservation ideas, strategies and behaviours limit the potential for landscape-scale restoration?
67. How can local communities be best engaged throughout the process of landscape restoration to ensure success?
68. How do we make ecological restoration knowledge widely accessible?
69. In what ways does public engagement through volunteering or citizen science build understanding and support for landscape restoration?
70. What is the most effective and socially just method of adjudicating and reducing social conflicts caused by restoration?
71. How can landscape restoration lead to an improvement in human health and wellbeing?
72. What is the impact of ecological restoration of marine ecosystems on human wellbeing and the lifestyle of people living in coastal areas?

73. Which restoration measures in urban habitats lead to measurably improved human wellbeing, and physical and mental health?

Policy and governance

The founding nature legislation in Europe, the EU Birds and Habitats Directives and the Council of Europe's Bern Convention, focuses on measures for the protection of species and designation of sites for presence of species or habitat types. These policy instruments have been relatively successful in creating extensive site networks (Natura 2000 and the Emerald Network) and conserving species (Sanderson et al. 2016, Amano et al. in press), but EU level assessments show that 77% of habitats have unfavourable status (EEA 2015). Several of the questions posed in this section relate to the opportunities for landscape restoration provided by current policy and legislation, and how monitoring and reporting against these can be made more effective and robust. Approaches to maximising the effectiveness of policy, by reducing corruption and perverse subsidies, as well as allowing innovative approaches (with their associated uncertainty of outcome) were also considered important.

Meeting ambitions for restoration at a landscape scale, which often requires cooperation across national or sub-national borders, will depend on a wide range of policy frameworks, most importantly the Common Agricultural Policy (CAP), which influences over half of the EU land surface and currently accounts for approximately 40% of the EU budget. Agricultural policy and nature conservation policy in Europe, however, have not always been fully and consistently aligned (Hodge et al. 2015). It has been recently recognised that post-2020 the CAP needs to contribute more to the achievement of environmental and climate objectives (European Commission 2017), particularly under a changing climate. The development of new policies could provide strong incentives to strengthen and expand landscape restoration programmes, leading to a number of questions asking how we can improve and integrate policies for the restoration of specific habitats. Although the modifications in land use associated with changes in climate and policy may provide new opportunities for restoration, potential consequences could include the displacement of unsustainable operations outside Europe, where environmental legislation may be less rigorously applied.

74. What are the opportunities and challenges presented by protected areas and related legislation for landscape restoration?
75. How are we going to evaluate and communicate ecological restoration outcomes against relevant local, national and international commitments?
76. Which landscape restoration activities are required to strengthen the connectivity of the Natura 2000 network?
77. How robust has the monitoring used to report against the Aichi targets on restoration been and what lessons can we learn?
78. What are the relative benefits of ecological restoration at the landscape scale versus the summed total of an equivalent area of dispersed site-based restoration actions?
79. How do we incorporate uncertainty, and allow innovation and risk-taking in ecological restoration?
80. How does governance failure, such as corruption, influence the effectiveness of landscape restoration?
81. Which perverse public subsidies restrict landscape restoration, and what mechanisms could be put in place to prevent this?
82. Which changes to agricultural policies and subsidies, including the CAP, would best enable European landscape restoration and what would be the political, social, financial and ecological outcomes?

83. How can EU agriculture, environment and land use policy and legislation better recognise, maintain, restore and support biodiverse wood pastures and scattered open grown trees?
84. What are the policy options for driving and supporting the large-scale restoration and rewetting of high organic and peat soils that is needed to combat land degradation and reduce greenhouse gas emissions?
85. What are the barriers to and opportunities for coherent policy and governance for ecological restoration of intertidal and transitional waters and marine ecosystems?
86. Which policies could incentivise and support the restoration of degraded landscapes damaged or at risk of fire in the Mediterranean region?
87. What are the obstacles to the restoration of free-flowing rivers and their estuaries, and how can they be overcome?
88. How, and to what extent, can former and current military areas contribute to landscape-scale restoration?
89. How can renewable energy targets be balanced with those of restoration?
90. What are the opportunities and challenges for restoration caused by changes in land use due to climate change?
91. To what extent will landscape restoration displace environmental impacts to areas outside Europe, and how significant is this for biodiversity conservation?

Economics

The profound pressures on biodiverse landscapes in Europe demand urgent conservation action, yet resources are everywhere limited. Choices therefore have to be made in the allocation of resources between competing conservation strategies, and an assessment of cost-effectiveness (for example between restoration and protection strategies) has become an important element in conservation planning (Moran et al. 2010). However, most restoration is still conducted without a clearly defined analysis of costs or measurement of success against specific goals (Kimball et al. 2015; Nunes et al. 2016), and methodological questions remain about how these should be quantified. Other issues with considerable relevance to the acceptance and delivery of large-scale ecological restoration include the effective deployment of resources and the social distribution of benefits accrued. Land tenure can greatly influence the choices adopted and positions held with regard to land use and management (Adams et al. 2014), as demonstrated with regard to woodland and forest creation (Lobley et al. 2012), and can be particularly complex in landscape scale programmes. The common ownership of the seabed throughout much of Europe also creates challenges in this context. We draw attention to the potential of different kinds of financial instruments available to support landscape restoration, and the incentives and disincentives for private landowners, particularly farmers (Hodge 2016). Novel or currently under-utilised funding models could also be usefully investigated.

92. How do we prioritise conservation investment between maintaining and enhancing existing natural habitat and restoring degraded land?
93. How do the economic inputs and outputs of rewilded landscapes, with large areas under non-intervention management, compare with conventionally managed landscapes?
94. How can we better understand the long-term costs and benefits of the restoration of large, unmanaged areas?
95. What are the costs of inaction, in terms of biodiversity and economics, in waiting too long to begin a restoration project?
96. How can the ‘polluter pays’ principle be used to facilitate restoration?
97. Which financial instruments and models are and could be most effective in enabling European landscape restoration?
98. What is the business case for the private sector to engage in landscape restoration, and how can it be developed?

99. What opportunities for landscape restoration are offered by engagement with developers, industry and infrastructure planners?
100. How does the form of land tenure (owned, leased, rented, shared) affect the opportunities for and outcomes of landscape restoration projects in Europe?
101. How can the costs and benefits from landscape restoration be equitably distributed?

Discussion

Ecological restoration is an increasingly important element in strategies aimed at not only reducing biodiversity loss but also reversing its declines, and is especially relevant in the intensively managed, farmed, urbanised and industrialised landscapes common in Europe. The growing research effort investigating larger-scale ecological processes and connectivity (such as the needs of migratory species, the impacts of climate change on species' ranges, and the need to restore ecosystem function) is increasingly focusing attention on large or landscape-scale conservation and restoration (Boitani et al. 2007, Adams et al. 2014). The questions presented in this paper highlight areas where this research could usefully be focused, in order to ensure that restoration projects are carried out in the most appropriate locations, using the best methods and effectively including all stakeholders, in order to maximise their success.

The opportunities for landscape restoration are affected by a wide range of natural and socio-economic factors, many of which are changing at an increasingly rapid rate in Europe and beyond. These include: changes in rural economies and widespread land abandonment (Pereira & Navarro 2015); changes in wider food production and distribution systems and diets (such as shifts in the demand and supply of meat, soya and edible oils; Ericksen 2008); changes in climate (such as seasonality, the incidence of novel crop diseases, and the incidence of extreme weather events; e.g. Morecroft & Speakman 2015); changes in farming systems (including agricultural mechanisation, fertiliser and pesticide production); changes in patterns of recreation (due to factors such as cheap air flights and road construction); changes in the services demanded of rural ecosystems (shifting from production, to social, cultural, recreation and other ecosystem services) and changes in interregional flows of services (due to changing trade and consumption patterns; Liu et al. 2015). These changing patterns of land use are likely to create challenges, but also opportunities for landscape restoration. Consequently, ensuring that we have the knowledge and understanding to prioritise restoration efforts in the most appropriate and beneficial areas, and apply the most effective approaches is becoming ever more necessary.

Landscape restoration is therefore a topic of significance for biodiversity conservation, rural policy and spatial planning throughout Europe. This exercise has identified 100 priority questions relevant to landscape restoration that should inform all three areas of concern. Our emphasis has been on projects of large spatial extent and this led to the identification of issues that are distinct from restoration and management on more local scales. In particular, social, cultural and economic factors form a significant element among the questions. These are especially relevant to large-scale projects, which incorporate a number of different habitats, almost always including those used or inhabited by people. Therefore, a wide range of stakeholders will need to be consulted, and community support and social buy-in will be essential for long-term restoration success. The mosaic of habitats and the regional and interregional flow of ecosystem services at a landscape scale also led to an emphasis on questions relating to connectivity (these questions spanned several of the sections: conservation of biodiversity, natural processes and ecosystem services). Improving our understanding of these interrelations will be vital for effective large-scale restoration.

Along with a larger spatial scale, landscape restoration projects often have a long-term plan and vision (e.g. the Wicken Vision in the Cambridgeshire fens has a 100 year vision (Hughes et al. 2011), and the Cairngorms Connect project in the Scottish Highlands a 200 year vision) whereas others are open-ended and do not have a defined end date (e.g. Wild Ennerdale, Browning & Yanik 2004). However, as many of the questions reflect, great uncertainty remains around spatial and temporal scales, and the circumstances under which smaller-scale projects could eventually contribute to accumulated larger-scale and longer-term benefits. Equally, there is uncertainty in how to identify and prioritise the locations where these efforts would be most effective.

The knowledge gaps revealed here suggest that interest in long-term landscape-scale restoration projects may be advancing ahead of the knowledge base. This is unsurprising given the recent rise in interest and practice of large-scale ecosystem restoration, the short time that most existing projects have been in place and the rather limited resources allocated to monitoring and assessment of condition at the outset. In addition, these landscapes will continue to change, meaning that static targets, of the type we are used to measuring in 'conventional conservation', become less relevant. Consequently, success becomes more difficult to recognise, as the focus shifts away from specific targets for the abundance of each species and the location and size of every habitat towards the restoration of dynamic physical and biological processes. The changing relationships between these processes, species and habitats is also an important area for research and monitoring, in order to gain understanding of how and why these relationships change through time. Identifying less predictable but still meaningful goals remains an important challenge, and surveillance, rather than monitoring against targets, might be a more useful approach over the long-term. This also has implications for committed long-term funding, backed by suitable policy instruments. Such commitment is unusual, but can be seen, for example, in the Swiss Government's 80-year long river restoration and monitoring programme (Weber et al. 2017).

The questions presented here also highlight the fact that there may be differences in the objectives of restoration and in the views on the most appropriate methods and approaches to be used. This may lead to tensions in practice, reflected in some of the questions presented here. For example, question 39 asks how restoration can lead to ecosystems that better emulate natural processes, whereas question 49 focuses on managing ecosystems in order to optimise delivery of ecosystem services. The answers to these questions, both focusing on management of ecosystems, are likely to be different. However, having answers to both these questions would allow someone implementing a landscape restoration project to make a better-informed management decision, appropriate to the context of their project and its specific objectives. Ultimately, policy and management responses to the knowledge gained by answering these questions are likely to depend on a range of other factors, such as social factors, values, financial constraints and the wider policy context, but it seems clear that making such decisions with the best possible understanding of the options is desirable.

A number of questions relate to particular haibtats, with eight questions specifically referring to restoration in the marine habitat. There has been a recent rise in interest in carrying out major marine restoration interventions, due to increasing concern about the long-term degradation of European oceans and the resources they support. Current marine and coastal conservation measures operate primarily by regulating human behaviour rather than by physical interventions. In many locations and in some habitats there exists a strong basis for such management, but several questions proposed here indicate a changing focus towards active restoration. Improvements in the methods for the restoration of marine and coastal habitats, such as oyster beds and seagrass meadows, are paving the way for the consideration of more fundamental processes (e.g. feedbacks) associated with the restoration of the marine environment (Maxwell et al. 2017).

It is an exciting time for landscape-scale restoration projects across Europe, and we hope that the questions posed here will encourage research and focus efforts, to allow the increased implementation and effectiveness of these programmes. Several suggestions have already been put forward of how to begin to address these issues, whether by meta-analyses, literature reviews or field studies, and we hope that others will also be inspired.

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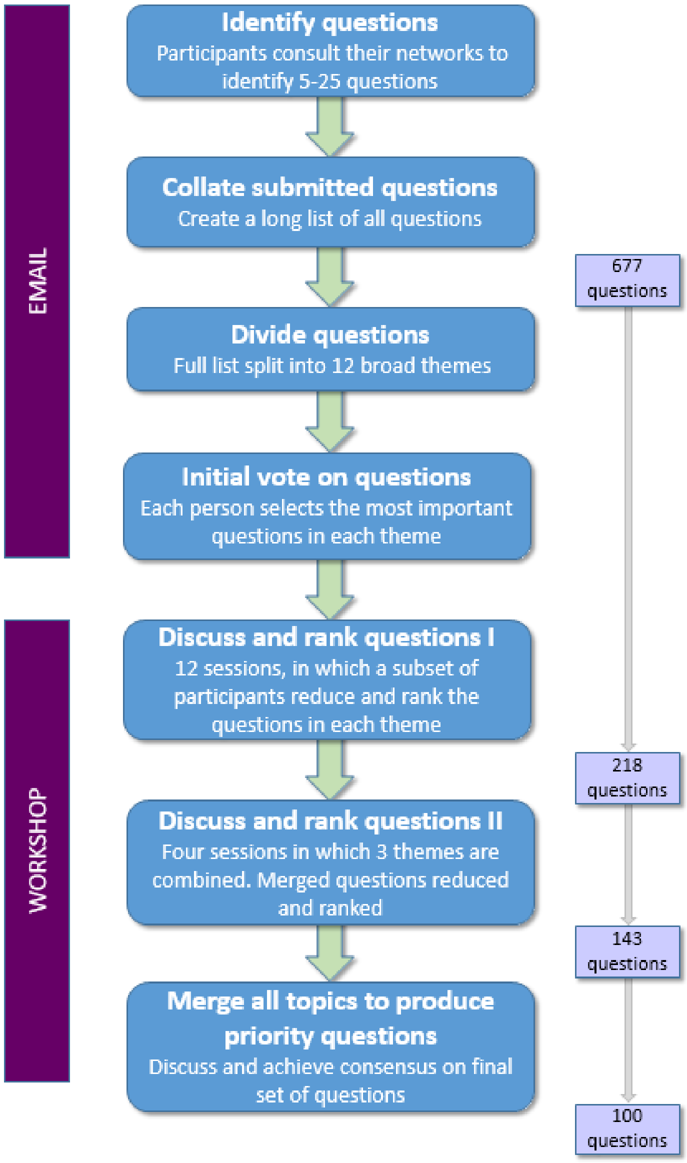

Figure 1. The stages used to identify and then prioritise questions in the exercise.

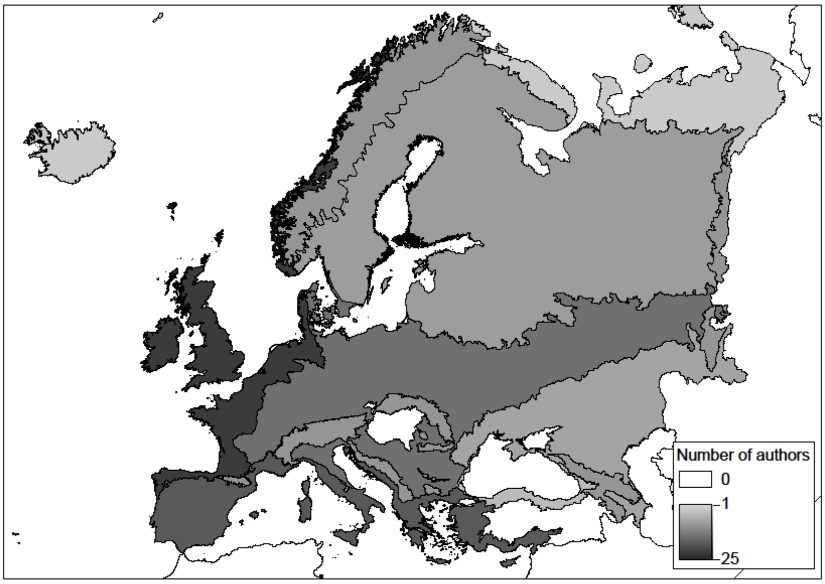

Figure 2. Map showing number of participants in the exercise that have experience of working in each of the biogeographical regions of Europe.