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Research

Expert-based assessment of rewilding indicates progress at site-level, yet challenges for upscaling

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Rewilding is gaining importance across Europe, as agricultural abandonment trajectories provide opportunities for large-scale ecosystem restoration. However, its effective implementation is hitherto limited, in part due to a lack of monitoring of rewilding interventions and their interactions. Here, we provide a first assessment of rewilding progress across seven European sites. Using an iterative and participatory Delphi technique to standardize and analyze expert-based knowledge of these sites, we 1) map rewilding interventions onto the three central components of the rewilding framework (i.e. stochastic disturbances, trophic complexity and dispersal), 2) assess rewilding progress by quantifying 19 indicators spanning human forcing and ecological integrity and 3) compile key success and threat factors for rewilding progress. We find that the most common interventions were keystone species reintroductions, whereas the least common targeted stochastic disturbances. We find that rewilding scores have improved in five sites, but declined in two, partly due to competing socio-economic trends. Major threats for rewilding progress are related to land-use intensification policies and persecution of keystone species. Major determinants of rewilding success are its societal appeal and socio-economic benefits to local people. We provide an assessment of rewilding that is crucial in improving its restoration outcomes and informed implementation at scale across Europe in this decade of ecosystem restoration.

Keywords: Delphi technique, expert elicitation, monitoring, restoration, rewilding, rewilding interventions

Introduction

The large-scale restoration of functioning ecosystems is essential in halting two of the most pressing issues of this century; species extinctions and climate change (IPBES 2019, IPCC 2019). Rewilding has emerged as an important tool to restore natural, dynamic processes in a self-sustaining way across large areas of degraded or abandoned land, as well as promoting the comeback of threatened keystone species (Svenning et al. 2016, Fernández 2017, Perino et al. 2019). Widespread land abandonment and recoveries in populations of many megafauna species across Europe are leading to passive rewilding, as well as increasing the potential for active rewilding (Navarro and Pereira 2015, Linnell et al. 2020). Consequently, the concept of rewilding is gaining interest among conservation practitioners and the public as a tool to restore nature at scale (Jepson 2019). However, both the application and upscaling of rewilding beyond pilot sites remains limited, in part, due to a lack of monitoring, with the long-term consequences of rewilding interactions still poorly understood (Torres et al. 2018).

To date, our understanding of rewilding progress has often been limited to studying non-intentional rewilding events, or the consequences of one dimension of rewilding in isolation, e.g. the impact of one species reintroduction (Bakker and Svenning 2018). Furthermore, there is little understanding of what interventions are being used by rewilding practitioners and how these impact the ecological integrity of a site. With limited empirical evidence underlying the conceptual framework of rewilding, there is, in turn, limited capacity either to persuade policy-makers and funders to support the implementation of rewilding at scale or to inform more targeted interventions in the future (Pettorelli et al. 2018). Therefore, there remains the urgent need to support comprehensive assessments of rewilding sites over time and to understand how interventions have translated into ecological and socio-economic changes.

A key challenge of quantifying rewilding progress lies in the ability to capture its multiple dimensions, spanning socio-economic and ecological responses. In response to data paucity, expert elicitation is an increasingly common tool to assess dynamic and complex systems (Martin et al. 2012). Environmental and conservation organizations often use expert-based assessments to make informed and quick decisions for policy-relevant questions, such as for the red-listing of ecosystems or evaluating the effectiveness of conservation interventions (IUCN 2015, Bolam et al. 2020). However, just as with empirical data, expert assessments must be scrutinized to minimize biases. Substantial effort has been placed on developing techniques to deal with these issues (Kynn et al. 2008).

One increasingly popular method for minimizing biases and standardizing expert assessments is the Delphi technique. This is an iterative, participatory method used for collecting and formalizing expert-based knowledge (Hemming et al. 2018). The technique provides the possibility for reconsideration of initial responses in the light of the comments of others in the panel (Sutherland et al. 2011), and has been shown to generate more accurate and transparent assessments in conservation ecology (Burgman et al. 2011). It fills in data gaps through the lived experience of the participants (O'Neill et al. 2008, Ochoa-Gaona et al. 2010) and aims to integrate different disciplines and/or geographic locations (Bolam et al. 2020). This is particularly relevant in assessments where the outcome is dependent on different perspectives and expertise of respondents. Applying the Delphi technique can thus provide an inclusive expert judgment of complex and participatory restoration interventions.

Here, we apply the Delphi technique to a multidimensional monitoring framework to a) improve a reproducible process for cost-effective periodic assessment of rewilding and b) produce the first comprehensive assessment of rewilding progress across seven sites in Europe. More specifically, we assess whether the Delphi technique can help generate standardized, calibrated applications of the monitoring framework across sites. We identify what interventions are being applied to rewilding sites and at what scale. Further, we measure the progress made across sites and identify the challenges for upscaling rewilding in these sites. Finally, we assess the major factors benefitting or threatening rewilding progress as identified by rewilding practitioners. The process and assessment presented here are a critical step towards understanding and predicting the factors that are important for rewilding success and scaling up its implementation in this decade of ecosystem restoration.

Methods

Quantifying rewilding progress

We quantified rewilding progress in seven sites across Europe: Central Apennines, Greater Côa Valley, Oder Delta, southern Carpathians, Rhodope Mountains and Danube Delta (Fig. 3, Table 1). These sites form part of a coordinated rewilding network (<https://rewildingeurope.com/>) which aim to trial the implementation of rewilding on pilot sites. The sites were established in areas of ongoing land abandonment and span different ecological and geographical regions across Europe. We quantified changes over time across the three central components of rewilding identified in a recently proposed rewilding framework: stochastic disturbance, trophic complexity and dispersal (Perino et al. 2019). These components aim to encompass key ecological processes that are essential for self-organizing and complex systems. In order to do so, we expanded these three components into a total of 19 indicators that quantify the amount of human forcing and the state of ecological integrity over time (Torres et al. 2018). These indicators were specifically designed to be scale-independent and to account for a wide range of ecological and societal contexts, as well as active and passive rewilding processes. For each of the indicators, the baseline (i.e. starting year of intervention, Table 1) and the current (November 2020) state of the site were assessed by the local experts. We calculated the rewilding score as the geometric mean across the 19 indicator scores in accordance with Torres et al. (2018). Score changes over time were calculated as the relative percentage difference between baseline and current scores.

Applying the Delphi technique

We ran a six-step Delphi expert elicitation technique following the IDEA protocol (Investigate, Discuss, Estimate, Aggregate;

Table 1. Inventory of the main rewilding interventions applied per site, characterized by the three ecological rewilding components and socio-economic measures.

Site (yr)	Size (km^2)	Interventions			
		Connectivity and composition	Trophic complexity	Stochastic disturbances	Socio-economic
Central Apennines (2012)	75.5	- Wildlife corridors created between protected areas - Infrastructure permeability measures (e.g. wildlife passages) - Removal of linear infrastructure	- Reintroduction of herbivore and threatened species	NA	- Outreach and education - Human–wildlife coexistence measures (e.g. compensation programs) - Ecotourism established
Greater Côa Valley (2012)	44.7	- Wildlife corridors created - Native seed planting	- Herbivore reintroductions (semi-wild horses, wild cattle, roe deer) - No-take hunting zones created - Vulture feeding stations established	- Removal of sheep grazing - Grazing for fire regime regulation	- Ecotourism established
Danube Delta (2011)	63.9	- Dam removals - Restoration of water channels - Lateral river connectivity improved - Protected area establishment - Halt of invasive species stocking in water bodies	- Reintroduction of herbivore and threatened species (water buffalo, semi-wild horses, red and fallow deer, eagle owl, steppe marmot, kulan) - Supplementary feeding of recently reintroduced, threatened populations	- Rewetting and flooding of lakes and polders	- Ecotourism established
Velebit Mountains (2012)	95.5	- Water body restoration	- No-take hunting zones established - Reintroduction of herbivore species (semi-wild horses, wild cattle, red deer)	NA	- Stakeholder engagement - Ecotourism established
Oder Delta (2014)	78.3	- Lateral river connectivity improved - Halt of invasive species stocking in water bodies	- No-take fishing zones established - Spawning sites restored	- Rewetting of polder and grassland areas - Ecological alluvial forest management introduced	- Land purchases - Ecotourism established
Rhodope Mountains (2011)	13.5	NA	- Herbivore species reintroductions (red and fallow deer, bison, semi-wild horses)	NA	- Ecotourism established
Southern Carpathians (2012)	13.8	- Hunting pressures reduced	- Herbivore species reintroductions (bison)	NA	- Ecotourism established - Education and outreach - Wildlife–human coexistence measures

Figure 1. Steps taken for the iterative monitoring process. Graphic representation of the steps taken for applying the Delphi technique to score rewilding progress across sites at different scales and across varying landscapes.

Hemming et al. 2018) as outlined by Mukherjee et al. (2015) for ecological and biological conservation (Fig. 1). We applied this process to account for subjective and biased reporting on the indicator scores, as well as a lack of original consensus over the indicators' meaning and the data that should be used for scoring. As part of the process, we also compiled an inventory of the main rewilding interventions categorized by the three central components of the rewilding framework, and one additional socio-economic dimension to incorporate measures that were societally, and not ecologically, focused. Within the process, we further elicited a list of key success and threat factors as identified by the practitioners for their sites.

We adapted the original indicators into an accessible questionnaire for a non-scientific audience (Supporting information). Then, we selected and invited experts for each site to participate (n = 18). These included local practitioners, technicians, scientists and regional managers who work with and understand the sites. This approach ensures a wide range of perspectives and can improve on information biases (Hemming et al. 2018). The process for choosing the participants was purposive, with experts selected conditional on whether they fit into at least one of the following criteria:

1. local practitioners/experts who have a long-term overview of the site and are able to provide detailed information about how the site has changed over time (≥ one per site) and/or,
2. regional managers who have worked across several sites and are able to provide comparative information to 'control' for scoring the indicators and complement the local practitioners' knowledge of their site and/or,
3. technicians and GIS experts who work across all or at least one site and who helped collect and analyze the data used to score the indicators wherever available and/or,
4. scientists who are considered experts in rewilding and are familiar with the monitoring methodology (published at least one peer-reviewed paper on the topic).

We had at least one participant from each criterion that was an expert for one or multiple sites to ensure that the range of different perspectives was kept constant across the sites.

We started by providing individual clarification sessions informing on the objective of this analysis. Participants were then asked to complete the questionnaire individually per team and were given time to collect relevant data. We analyzed responses and compiled them into a report, which was used in the next scoring iteration. For each indicator, we prepared results with the summary of scores across sites at baseline, and score changes over time (Supporting information). This stage was essential for participants to be able to evaluate the results in comparison to other sites, as well as be able to explain and reconsider their assessment in the next iteration. Subsequently, we conducted a workshop with all participants together. Per indicator, two sites were chosen randomly to report the methodology for scoring and the context of their site for that score. We then specifically asked:

a) Given the scorings and explanations provided for other sites, did you score similarly or differently?
b) Did you apply the indicator in the same way as the other sites, and if not, why not?

This stimulated discussion on the context of the sites, their reasons for scoring, as well as the indicators themselves. The discussions elicited a consensus agreement on the interpretation of the indicator and what should be taken into account for scoring. Each participant was then given time to evaluate, and if necessary, rescore their sites in light of the group responses.

Results

Rewilding interventions

The active rewilding interventions that most often occurred across the sites in various landscapes were predominately focused on species reintroductions or population reinforcements. These measures focused on keystone and large herbivore species and in some cases, threatened, culturally important species. Cattle and horses are fenced, except in Danube Delta, and all other species are free roaming. In three areas, no-take zones were established to increase the viability of hunted and reintroduced species. Additionally, work was conducted across five sites to improve the connectivity of sites and establish wildlife corridors, either by removing infrastructure such as dams and fences, or through land purchases and protected area designations. However, the major ecological components of rewilding (i.e. connectivity and composition, trophic complexity, stochastic disturbances) were dissimilarly addressed across sites, with only three sites including interventions for all components and only three sites addressing the restoration of stochastic disturbances (Table 1). In addition to the ecological components outlined by the original framework, socio-economic measures were also widespread across all the sites aiming at improving human–wildlife coexistence and introducing alternative nature-based economic opportunities. The most common intervention was the establishment of ecotourism through wildlife safaris, bird watching hides and guided tours. Another important socio-economic intervention was human–wildlife coexistence measures, e.g. through compensation programs for wildlife damage.

Changes in rewilding score

We recorded increases in rewilding score over time in five of the seven sites, whilst two sites reported decreases (Fig. 2). The five sites with overall increases in rewilding scores reported decreases in human forcing, and four of the sites reported increases in ecological integrity (Supporting information for all indicator scores per site). The biggest improvement over time was reported in the Central Apennines, with a relative increase of 47.1% from 2012 to 2020, and improvements in 14 of the 19 indicators. Rhodope Mountains reported the largest decrease in rewilding score over time, with a change of −13% from 2011 to 2020. Both, the Rhodope Mountains and Velebit Mountains decrease are attributable to an increase in the amount of human forcing on the site over time (43.4% and 9.8% respectively), despite a minor improvement in ecological integrity for the Rhodope Mountains (1.1%). The increases in human forcing were attributable to a) population reinforcements and artificial feeding of wildlife, either due to hunting or temporary rewilding interventions and b) increases in land-use intensity such as agricultural expansion.

Effects of the Delphi technique

The Delphi technique allowed participants to reevaluate their scores in light of standardized information and consensus understanding of the indicators (Fig. 3, Supporting information for all indicator changes per site). Absolute changes in rewilding score as a result of the Delphi exercise ranged from 2.1 to 56.8% across sites. Furthermore, the results became more similar as a result of the process with reduced extreme values. The range of % change across sites decreased from −22.6 to 100% (SD = 40.3) pre-Delphi to −13.0 to 43.2% (SD = 19.7) post-Delphi. Overall, four sites reported increased scores and three sites reported decreased scores after the Delphi process. The main drivers of score change were misunderstandings about the meaning of each indicator, what data should be used to evaluate the indicators and what components should be taken into consideration for scoring, e.g. illegal activity for management indicators. Furthermore, a revised set of indicator descriptions and reference scores was then produced from the consensus agreement about what should be measured (see the Supporting information for the updated list).

Rewilding progress and threat factors

The most important progress factors were predominately focused around the appeal of rewilding as a concept and effective communication about the sites' results (Fig. 4a). Socio-economic factors were also commonly highlighted, such as bringing economic opportunities to the area and having good working relationships with stakeholders. Alongside the socio-economic factors, effective species management was also considered to play an important role in driving rewilding progress. The threat factor which affected all sites was poaching. These were attributed by the experts to lead to declines in species' populations that cannot be officially monitored or

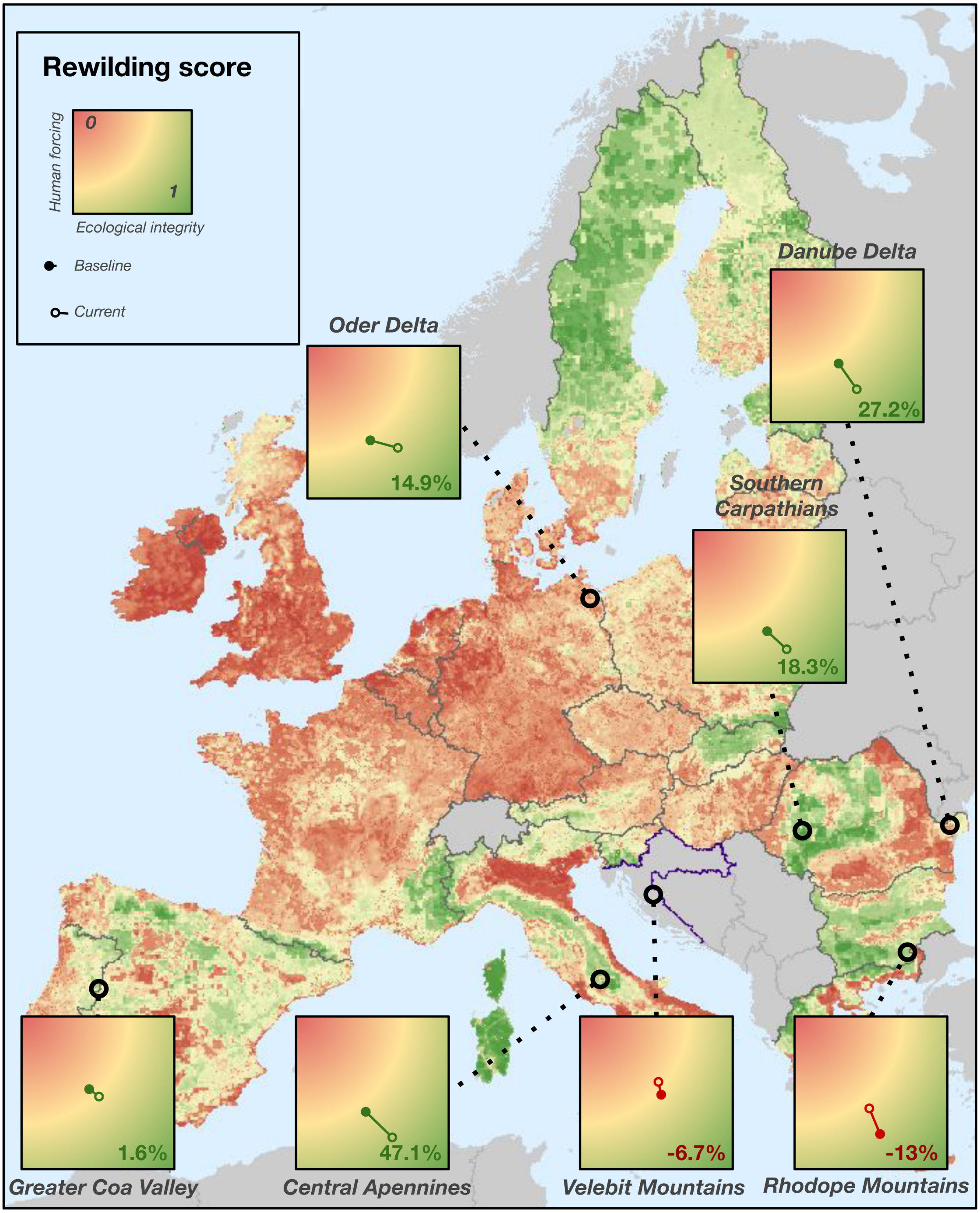

Figure 2. Map of the seven study sites across Europe and their corresponding changes in rewilding score over time. The underlying base map represents the ecological integrity measured at the European scale for the year 2012 (the average baseline year for the sites), and assessed using the same underlying rewilding framework from Torres et al. (2018) (base map credit: Fernández et al. 2020). The study sites are measured using the rewilding score which integrates ecological integrity (x-axis) and human forcing (y-axis), whereas the base map comprises just ecological integrity. For each site, the baseline rewilding score is depicted by the filled circle and the current rewilding score is depicted by the empty circle.

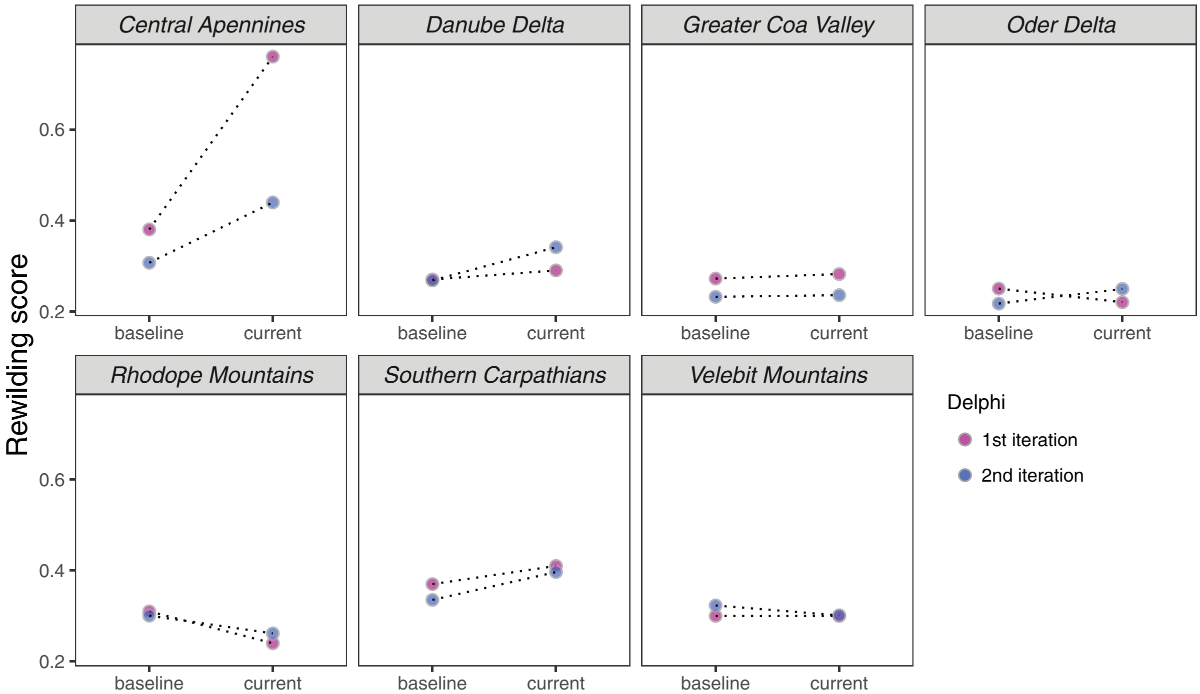

Figure 3. The change in rewilding score over time as a result of the Delphi exercise per study site. The first iteration scores were those conducted per team and the second iteration scores scores were those elicited collaboratively from the workshop with all experts across sites together.

regulated. Additionally, policies, specifically subsidies from the Common Agricultural Policy were also considered a major threat to many sites due to economic incentives for increasing intensive land use through agricultural expansion. Other important factors which were perceived as threatening rewilding progress were land/water use change and management factors which referred to actions that could increase the amount of human forcing on the site.

Discussion

In the UN decade of restoration, it is increasingly vital that we understand how restoration has progressed, in order to use resources more effectively and scale up efforts accordingly. In spite of substantial efforts to improve monitoring, there remains a paucity of long-term, comprehensive assessments in restoration and in particular, rewilding sites (Wortley et al. 2013, Rubenstein and Rubenstein 2016). Using a participatory, iterative technique for eliciting expert-based knowledge, we calibrated and standardized 19 indicators in order to undertake the first comprehensive assessment of rewilding progress across seven sites in Europe. By quantifying changes in human forcing and ecological integrity, we found that sites are improving in several ecological parameters, with five of the seven sites seeing overall progress along the rewilding scale. However, several indicators consistently failed to change or indicated degradation. Score changes were both the result of directed rewilding interventions and broader, socio-economic trends or competing land uses. Overall, our results suggest that whilst there have been improvements across several dimensions of rewilding, current efforts cannot always revert broader land use and policy pressures.

We employed the Delphi technique in order to improve on the main challenges that we identified in the first scoring iteration, such as differences in understanding and quantifying the indicators among experts. Through consensus decision, we co-produced revised indicator definitions that more fully captured which components should be measured and how these indicators can be quantified (Supporting information). Furthermore, we came to a consensus as to how the reference scoring for each indicator should be standardized, and what state or process constitutes a low, mid or high score. This was important in order to calibrate measurements across sites and spatiotemporal scales, which has often been a limitation of expert-based monitoring schemes (Kapos et al. 2008, Eycott et al. 2011). The technique also allowed participants to discuss and formalize what data should be used to score the indicators and what components should be taken into consideration for scoring, as well as clarify misunderstandings about the meaning of each indicator. This led to considerable score changes for some of the sites, most noticeably, Central Apennines and Oder Delta. Through fostering these group discussions and an improved understanding of the indicators, scores changed considerably across indicators and became more similar to each other across sites (Fig. 3, Supporting information).

Whilst the consensus indicator list is a further step towards facilitating and standardizing monitoring of rewilding progress across sites in Europe, there remain several challenges that

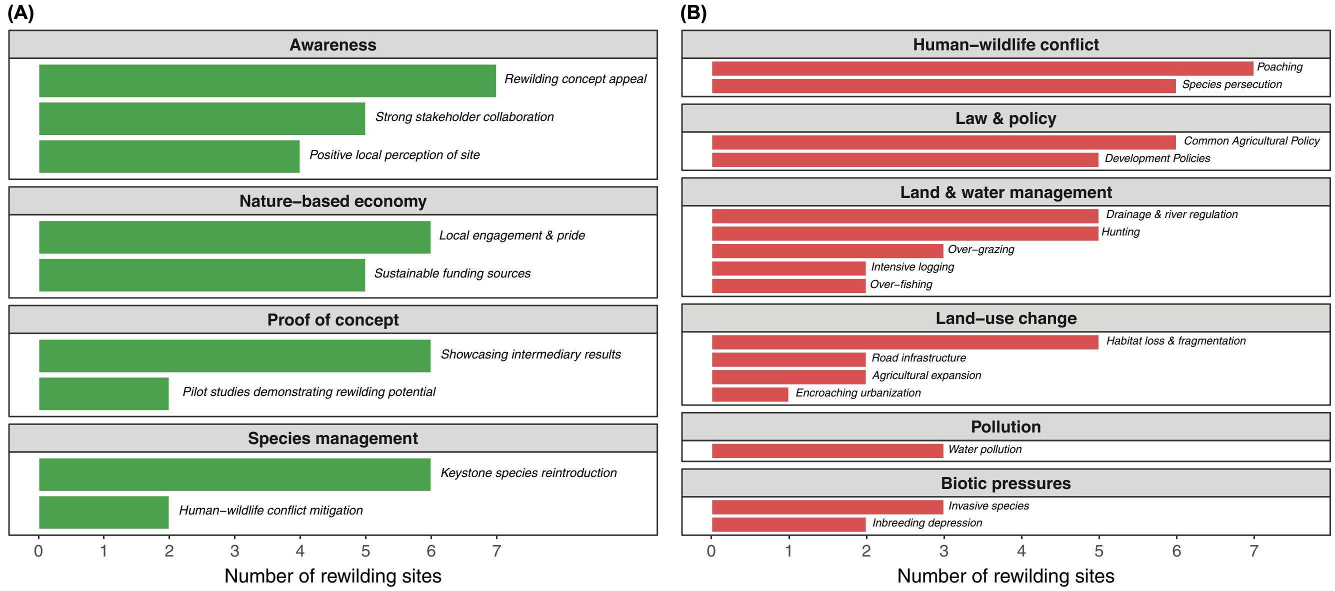

Figure 4. The (A) progress and (B) threat factors considered most important for the study sites by the practitioners. The length of each bar indicates the number of sites that each factor applies to. The factors were identified by the experts themselves during the workshop without previous input or classification.

should be addressed through future research. The process of scoring indicators currently remains limited in terms of attribution of rewilding interventions, with the scoring reflecting both directed and non-targeted actions in the landscape, potentially confounding the analysis. Future assessments may consider the potential for quasi-experimental methods such as synthetic controls for comparison studies to improve on this issue (Baylis et al. 2016). Furthermore, there is the need to combine expert judgement with analytical, data-driven approaches in order to empirically assess changes and determine whether the iterative scoring process brings the expert-based assessments closer to 'accurate' measurements. Where the monitoring of large-scale projects using ground-based measurements remains unfeasible due to resource restrictions, complementary data-driven approaches could harness remote sensing techniques and other cost-effective, repeatable methods for capturing the multi-dimensional components of landscape change (Andersen et al. 2017, Pettorelli et al. 2018).

The results of the iterative monitoring process revealed that while some indicators improved across sites, others remained consistently unchanged or deteriorated. Consistent improvements in trophic complexity across sites likely resulted from actions such as implementing no-take zones, mitigating human–wildlife conflicts and reintroducing or reinforcing keystone species populations, as well as European-wide natural recoveries in species populations (Navarro and Pereira 2015). In contrast, indicators related to stochastic disturbance regimes or land-use intensity consistently remained unchanged. This may be, in part, due to spatiotemporal constraints. Given that we report on intermediary progress (< 10 years), this time span may not have been long enough to capture shifts in natural disturbance regimes. Additionally, the spatial scale of the rewilding interventions is still limited and often restricted to small pilot sites, whilst broad-scale interventions are often required before regime shifts can be detected. For example, in the Greater Côa Valley, herbivore grazing was introduced to an area of ~ 9 km^2 within the site to regulate fire, however patterns of pyric herbivory establish at larger scales in a mosaic landscape (Falk et al. 2007, Fuhlendorf et al. 2009). Among other factors, the sites are mostly operating outside of protected areas and within a diverse land ownership matrix where there are often competing desires for land use that may undermine the ability for rewilding action to be implemented at scale.

Our findings further suggest that rewilding progress is often limited by regulations and policies that dictate land management and enable competing land uses (Fig. 4). For instance, regional regulations to support hunting practices, such as supplementary feeding and carrion removal can undermine scavenger ecology (Cortes-Avizanda et al. 2016, Kuijper et al. 2016), and regulations to reduce fire risk, such as deadwood removal, has been linked to reduced saproxylic biodiversity in forests (Seibold et al. 2015). More broadly, key funding mechanisms within the EU, such as agricultural subsidies under the Common Agricultural Policy are also either preventing increases in the rewilding score or actively reversing progress. Although rewilding operates predominately in areas of land abandonment, land trajectories are not static and can revert to agriculture given appropriate incentives (Munroe et al. 2021). For example, in the Rhopode Mountains, the trajectory towards land abandonment that began in the 1990s has recently been reversing back towards agricultural intensification and encroachment as a result of Common Agricultural Policy subsidies (Dobrev et al. 2014), with negative implications for rewilding progress in this area.

In order to counterbalance this threat, rural policies may need to be better targeted to allow people to make better use of the socio-economic benefits that rewilding can provide.

Overall, our results highlight that the long-term ability for rewilding to progress and scale-up is often subject to external pressures dictated outside the sites themselves. Many important, desired changes rely on legal or policy mechanisms which can only be affected through policy change at the national and EU scale. Therefore, whilst rewilding measures are beginning to make positive changes at local scales, future intervention efforts should be better complemented by policy and advocacy if rewilding is to become scalable across entire landscapes. Moreover, this highlights the need for better land use planning at the national level to determine where there is potential for rewilding, in order for subsidies and conservation efforts to be more effective long term. The public enthusiasm that has been instrumental for rewilding success (Genes et al. 2019, Jepson 2019; Fig. 4) thus far may be harnessed and channeled towards achieving these goals, allowing rewilding to scale up in this decade of ecosystem restoration.

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Author contributions

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