Copyright © 2016 by the author(s). Published here under license by the Resilience Alliance.
Nilsson, C., A. L. Aradottir, D. Hagen, G. Halldórsson, K. Høegh, R. J. Mitchell, K. Raulund-Rasmussen, K. Svavarsdóttir, A. Tolvanen, and S. D. Wilson. 2016. Evaluating the process of ecological restoration. *Ecology and Society* 21(1):41. http://dx.doi.org/10.5751/ES-08289-210141

Research, part of a Special Feature on Ecological Restoration, Ecosystem Services, and Land Use

Evaluating the process of ecological restoration

Christer Nilsson [1], Asa L. Aradottir [2], Dagmar Hagen [3], Guðmundur Halldórsson [4], Kenneth Høegh [5], Ruth J. Mitchell [6], Karsten Raulund-Rasmussen [7], Kristín Svavarsdóttir [4], Anne Tolvanen [8] and Scott D. Wilson [9]

ABSTRACT. We developed a conceptual framework for evaluating the process of ecological restoration and applied it to 10 examples of restoration projects in the northern hemisphere. We identified three major phases, planning, implementation, and monitoring, in the restoration process. We found that evaluation occurred both within and between the three phases, that it included both formal and informal components, and that it often had an impact on the performance of the projects. Most evaluations were short-term and only some parts of them were properly documented. Poor or short-term evaluation of the restoration process creates a risk that inefficient methods will continue to be used, which reduces the efficiency and effectiveness of restoration. To improve the restoration process and to transfer the knowledge to future projects, we argue for more formal, sustained evaluation procedures, involving all relevant stakeholders, and increased and improved documentation and dissemination of the results.

Key Words: *ecological restoration; evaluation; Northern Hemisphere; restoration implementation; restoration monitoring; restoration planning*

INTRODUCTION

The accelerating degradation of the world's ecosystems has fostered a counter-movement to mitigate destructive impacts (Le Houerou 2000, Novacek and Cleland 2001, Lal 2004, Bernhardt and Palmer 2011). The topics of ecosystem restoration and ecological restoration have thus received increasing attention worldwide (e.g., Erwin 2009, Schmutz et al. 2014, Barral et al. 2015). For the last two decades the Web of Science (WoS) reports 2876 scientific papers on "ecological restoration" by 7 December 2015, but only 36 papers before that time. Papers addressing "ecological restoration" combined with "evaluation" are, however, much less common—only 177 according to the WoS, by 7 December 2015; the first one from 1995. Still, ecological restoration, defined as an "intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability" (SER 2004), requires evaluation to document progress and inform adaptive management strategies (Williams 2011) in terms of the cost-efficiency of the restoration process and the positive effects on the recovery of degraded ecosystems. This is particularly important in complex systems (Gunderson and Light 2006). If many years pass before a restoration is evaluated, and if the restoration has failed, it follows that recovery will be delayed or failed. Ecosystems often require decades or centuries to recover after restoration has been initiated, especially in high latitude and high elevation ecosystems with short growing seasons (Forbes and McKendrick 2002, Campbell and Bergeron 2012). Under such circumstances, failures may be costly if repeated trials are required to restore the ecosystem (Aradóttir et al. 2013). To avoid problems arising from flawed design and implementation of restoration, the monitoring and evaluation of restoration should be given high priority.

A recent review of restoration in the Nordic countries indicates that ecological restoration projects in the region often completely lack formal evaluation (Halldórsson et al. 2012, Hagen et al. 2013). Other studies also show this to be the case in other parts of the world (e.g., Bernhardt et al. 2005, Suding 2011), although the number of empirical evaluations has increased during recent years (Wortley et al. 2013). If evaluation steps are properly described and justified, restoration processes can be improved in terms of cost-efficiency and ecosystem effects, and the lessons learned can be more easily transferred to other projects (Nilsson et al. 2015). Traditionally, evaluation has been equated to the monitoring of the postrestoration outcome, and such monitoring has often been restricted to a single or a few events (Kondolf and Micheli 1995, Zedler and Callaway 2000, Suding 2011). Such limited efforts are unlikely to provide a full picture of the restoration process and its outcomes. For more accurate and reliable results, restoration evaluation should be a continual activity that is an ongoing part of the entire restoration process (Allen et al. 2002). In other words, evaluation could consist of different subactions or steps during the entire restoration process from the beginning to the achievement of the restoration goal (Jungwirth et al. 2002, Hughes et al. 2011, Pander and Geist 2013). Another drawback is that the evaluations may often be too simple to allow reliable conclusions (Suding 2011, Morandi et al. 2014). These problems may backfire on the restoration itself in that project goals may not be reached and cost efficiency not secured, and future restorations not conducted.

The restoration process can be seen as consisting of three phases: planning, implementation, and monitoring (Hobbs and Norton 1996, Tischew et al. 2010). Actors responsible for each of these three phases should evaluate and improve their "within-phase" work, at least informally, to guide adaptive decision making, thus reducing risk of failure (Williams 2011, Loftin 2014). In addition, the interactions between restoration phases can also be evaluated. For example, the implementation of restoration requires that planners communicate with practitioners, i.e., the people responsible for the practical work ("This is how we want to restore"). Similarly, the monitoring benefits from communication between practitioners and monitoring experts ("This is how we restored"), and the monitoring teams need to pass on their findings to the planners ("This is what happened"). We propose

[1]Umeå University, [2]Agricultural University of Iceland, [3]Norwegian Institute for Nature Research, [4]Soil Conservation Service of Iceland, [5]Kujalleq Municipality, [6]The James Hutton Institute, Aberdeen, UK, [7]Department of Geosciences and Natural Resource Management, University of Copenhagen, Denmark, [8]Natural Resources Institute Finland, Department of Ecology, University of Oulu Finland, [9]Department of Biology, University of Regina

Table 1. Summary of the information used for evaluation, how the evaluation was made, and by whom in the six evaluation steps (Figs. 1 and 2).

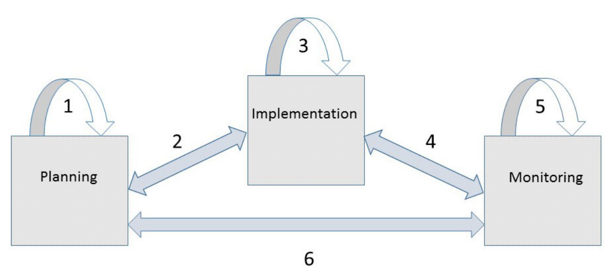
Evaluation step	What type of information was used as a basis for evaluation?	What was the information evaluated against?	How was the evaluation made?	How, by whom, and at what step were the results of the evaluation used?
1: Within planning	Information that restoration plan relied on	Ecological conditions, interests of landowners, funding agencies, and scientists	Meetings, discussions, and information exchange between planners, scientists, practitioners, and landowners	Planners used it to improve the planning
2: Between planning and implementation	Restoration plan, environmental and social conditions, experience from previous restoration actions	Local environmental and social conditions	Meetings, discussions, and information exchange between planners, scientists, practitioners, and landowners	Practitioners used the evaluation outcome for efficient implementation. Planners used it to improve the planning
3: Within implementation	Implementation experience, cultural and natural values, security, budget, logistics, societal views, science	Plans and directives, environmental impact assessments, laws	Discussions, negotiations, decisions	Contractors, planners, project owner
4: Between implementation and monitoring	Information on accomplished work, results of monitoring, informal observations	Plans and contracts, restoration and performance targets	Did restoration result in deviations from plans and contracts? Were results on target?	Practitioners got feedback to allow modifications of methods. Monitoring teams could adjust their methods based on information about implementation
5: Within monitoring	Data from replicated and standardized sampling, field visits with partners, photos	Native vegetation and unrestored plots	Evaluation against set goals or reference sites	Scientists used results for communication about future restorations. Preconceived ideas about outcomes could be difficult to overcome
6: Between monitoring and planning	Results of biotic, physical-chemical or socioeconomic monitoring of project outcomes	Project goals, reference sites, untreated controls	Types of communication evaluated	Feedback to planning and implementation phases. Well documented evaluation could benefit new projects

that all these three restoration phases can be improved by appropriate, within-phase as well as between-phase six-step evaluation (Fig. 1). In this paper, we discuss the relevance and usefulness of these 6 steps by analyzing 10 restoration projects in 8 northern countries. We ask the following questions: (1) Does the selected data set of 10 projects include examples of evaluation at each of the 6 steps?; (2) Are there examples, among the cases, of steps at which evaluation had an impact with respect to modification of current or future restoration projects?; (3) Based on the selected cases, what are the major limitations in the evaluation of restoration projects?

METHODS

We took inspiration from the paper by Hagen et al. (2013) who discussed ecosystem restoration in the Nordic countries. We searched for large, completed, or well-established, long-term restoration projects representing different ecosystem types, and added Greenland, Scotland, and Canada to cover a larger and more diverse area with such restoration projects. Among the preselected projects we chose 10 projects that fulfilled our criteria (Box 1). We included a variety of ecosystems typical of the northern hemisphere. We then analyzed the projects with respect to how evaluation had been made at the six steps, within-phase as well as between-phase as presented in Fig. 1. This analysis was made during an expert workshop where criteria for identifying the different evaluation steps were produced. We agreed that any type of value-laden information exchange within and between restoration phases could be categorized as evaluation. Because there were no previous frameworks available for such analyses, we constructed a new framework to assist in the data collection (Table 1). Our analysis then relied on information from scientific literature, reports, websites, oral communication with the restoration community, and our own knowledge about the specific projects. It should be noted that the selected case studies were chosen to illustrate the tool rather than to assess them per se. Given the diversity of restoration projects examined, we do not expect another choice of examples to produce very different results.

Fig. 1. Conceptual diagram showing the three major restoration phases and the six evaluation steps, three within-phase (1, 3, and 5) and three between-phase (2, 4, and 6), discussed in this paper. Evaluation steps are further described in the Introduction and in Table 1. Note that the evaluation process is not a single-loop, one-time practice; instead evaluation activity can go back and forth and be upheld during several years.



Box 1: Restoration projects analyzed in this paper.

Alpine heathland, Dovre Mountains, Norway. In 1999 the decision was taken to restore a 165 km² large military area of alpine heath, mires, and shrub vegetation, including the removal of 90 km of roads, 100 buildings, and large military installations to "reset the area for civilian use and to restore the ecosystem to its original state and for future nature conservation (National Park)" (Ministry of Defence 1998). The Norwegian Defence Estates Agency is responsible, and is both project owner and planner. Advisors in ecological restoration, pollution control, and construction work have been involved in planning, implementation, and monitoring during all parts of the project. The project period is 2008–2020 and this is so far the largest restoration project in Norway (Martinsen and Hagen 2010, Hagen and Evju 2013).

Alpine heathland, Nalunaq Goldmine, Greenland. Nalunaq Gold Mine, in southernmost West Greenland, was approved in 2003, and was operational to the end of 2013 (Dominy et al. 2006, Bell and Kolb 2013). A monitoring program mainly concentrated on the eventual pollution of different harmful elements. By November 2013, the mine closed and a local contractor from the town of Qaqortoq conducted a clean-up and restoration of the area, which was completed during the summer of 2014. The restoration of the mining area was mainly a visible clean-up of the site, meaning removal of all houses and physical installations, including bridges and drainage pipes. Restoration of vegetation was not conducted, therefore the areas with former activities and physical installations were still barren by the end of 2014. Environmental monitoring will continue for at least three years after the closure (2014–2016).

Birch woodland, Hekluskógar, Iceland. This project aims at restoring natural woodlands on about 900 km² of degraded land in the vicinity of the volcano Mt Hekla in South Iceland, to increase the resilience of the area against fall-out and secondary distribution of volcanic ash (Aradottir 2007, Óskarsson 2009*a, b*). Around 200 landowners participate in the project and the restoration takes place partly on their properties, but also to a large extent on public land. Actions involve establishment of plant cover and strategic establishment of seed sources of native birch and willows to facilitate natural distribution of woodlands. Restoration activities and results are regularly monitored and discussed with participating landowners (Óskarsson 2009*a,b*, 2011).

Rangeland, Farmers Heal the land (FHL), Iceland. This is a cost-share revegetation project aimed at enhancing restoration and improving rangeland management and stewardship (Arnalds 2005). About 600 landowners participate in the project and the restoration takes place on their properties. FHL is organized by the Soil Conservation Service of Iceland (SCSI), which provides extension services, seed and funding to buy fertilizers, while the farmers provide land, machinery, labor, and in some cases additional fertilizers and mulch. SCSI officers make annual or biennial visits to all participating farms, during which restoration activities are planned, discussed, and subjectively assessed (Arnalds 2005, Berglund et al. 2013). Thus, the FHL operates as an "umbrella," but much of the planning and monitoring are done on an individual farm basis. Information about restoration activities is kept in the SCSI database and has been used in ad hoc studies that involve more in-depth evaluation on a subset of the FHL. Examples involve studies on stakeholder interactions and experiences (Schmidt 2000, Berglund et al. 2013, Petursdottir et al. 2013*a*), vegetation succession (Elmarsdottir et al. 2003, Petursdottir et al. 2013*b*), and carbon sequestration (Aradóttir et al. 2000).

Forest and peatland in the Green Belt of Finland. Green Belt LIFE project encompassed restoration of 600 ha of forest, 362 ha of peatland, forest roads, and quarries in 13 Natura 2000 areas in the eastern Finnish region of the Fennoscandian Green Belt zone during 2004–2008. Established restoration methods developed for protected areas were principally used, and some alternative methods were experimentally tested. Intensive scientific monitoring was an essential part of the project, requiring continuous discussion between managers, planners, and scientists. The project is representative of LIFE projects targeted to forest and peatland restoration in Finland. Information on the project was compiled from scientific (Laine et al. 2011, Similä and Junninen 2012, Tarvainen et al. 2013, Hekkala et al. 2014*a,b*, Similä et al. 2014, Hägglund et al. 2015, Tarvainen and Tolvanen 2015) and public papers (Similä and Junninen 2012, Similä et al. 2014), project proposals, restoration plans, maps, and practical experiences.

Grasslands, northern Great Plains, Canada. Millions of ha of central North America have been planted to low-diversity, high-productivity introduced grasses, on both private lands (farms, ranches) and public areas (parks, common pastures, roadsides). Restoring diversity involves removing or decreasing these species and introducing native species. Ongoing annual evaluation revealed the surprising persistence of the introduced grasses (Bakker et al. 2003, Wilson and Pinno 2013). This challenge was addressed by a change in attitude: instead of completely removing introduced grasses, grazing was used to decrease their cover and incorporate them at a low abundance into the diverse community.

Montane grassland, Trotternish, Skye, Scotland. In response to Scottish Government concerns that excessive numbers of sheep were causing slope erosion on montane grassland, and were overgrazing grasslands within the Trotternish Ridge Special Area of Conservation, a vegetation and erosion monitoring program was set up in 1998. Small experimental plots were established on the steep slopes to enable monitoring of the effects of different grazing treatments on vegetation structure and erosion. The response to grazing removal was found to be very slow, with monitoring extended after 11 years for a further 6 years. During the time of this project other factors were also influencing the results: decline in number of farmers due to aging population and decline in sheep numbers due to changes in EU subsidies (Brown and Birnie 2012, Hewison et al. 2016).

Peatland, Caithness and Sutherland, Scotland. Restoration of peatlands and blanket bogs is occurring in many areas in Caithness and Sutherland. The restoration usually involves some form of drainage blocking to restore hydrological regimes, and where the area has been planted with commercial forestry, removal of the trees. Changes in hydrological regimes need to be carefully planned and the impacts on neighboring land taken into account. Some of this work has been funded by EU-LIFE projects with the evaluation of the project occurring in part during the reporting process of the projects (Lunt et al. 2010).

River, Skjern River, Denmark. In the 1960s the Skjern River was channelized and nearby meadows were ditched to increase agricultural production. After a few decades pollution due to N and P leaching and mobilization of ochre became obvious and it was decided to restore the river with a focus on pollutant removal. Different methods were much debated in the mid-1980s. The parliament decided in 1987 on a large restoration project focusing not only on cleaning processes but also on habitat improvements and recreation. The physical work, based on a construction law and environmental impact assessment from 1998, was implemented 1999–2002. Afterward stakeholders discussed the use of the area and scientists evaluated the outcome. The entire project is so far the largest restoration project in Denmark (Pedersen et al. 2007*a,b*, Pedersen 2010).

River, Vindel River LIFE, Sweden. This project, located in northern Sweden, restores the river network after the impact of timber-floating between the mid-1800s and 1976. Restoration measures include removal of structures like piers and dams, recreation of fish spawning beds, and diversification of channel morphology by putting back coarse sediment and tree trunks in channels. In some areas, experimental restoration has introduced large boulders from adjacent uplands into the channels (Gardeström et al. 2013). The results of the restoration are monitored, especially with respect to riparian vegetation and fish (Helfield et al. 2007, Palm et al. 2007, Polvi et al. 2014, Hasselquist et al. 2015, Nilsson et al. 2015).

RESULTS

We summarize our major findings on how the evaluation was made in the 10 chosen restoration projects (Box 1, Appendix 1), following the 6 steps in the conceptual framework model (Fig. 1, Table 1). For consistency, we standardized the names of the actors identified in each of the three phases of restoration, although we recognize that their actual roles and denotations varied between projects and countries. Thus, in short, planners planned, practitioners implemented, and monitoring teams monitored. Our framework for the evaluation of restoration (Table 1) was designed to maximize the information gained from the restoration projects that can be used to maximize the effectiveness of future restorations. We are aware that some evaluations encompass two or more of the six steps. For the sake of simplicity, however, we assigned them to the step where they had their main focus. It was not possible to consistently collect information on the types of evaluation metrics or qualitative information types used in the different projects. For this reason, the assignment of scores or ratings for the quality of evaluations was not possible. On the other hand, a scoring framework could add substantial value to the evaluation process. To make such a framework meaningful, however, restoration actors would be required to document their evaluation steps very carefully, and this was not the case in the chosen examples. Irrespective of the type of evaluation data, however, oral interaction between actors was the most common and effective way of sharing information. It should also be stated that our goal was not to provide detailed descriptions of the evaluations that had been done. Our main goal was to describe when and how evaluation should be done, with examples of how it influenced restoration.

Step 1: Evaluation within planning

All projects included some form of evaluation and adjustment of original ideas during planning. However, the choice of partners in this process differed between projects. In most cases evaluation involved interaction between restoration practitioners and landowners. In a few cases evaluation and adjustment of plans were made by restoration practitioners and experts together (e.g., Dovre Mountains in Norway and Green Belt LIFE in eastern Finland; LIFE is the EU's financial instrument supporting environmental, nature conservation and climate action projects throughout the EU). There were examples when restoration practitioners involved more partners in addition to landowners, such as governmental bodies, funding agencies, NGOs, scientists, and conservationists (e.g., Skjern River in Denmark). There were several examples of changes made to the plan based on the evaluation. In the Vindel River LIFE restoration project in Sweden, a dialogue with landowners resulted in (temporary) withdrawal of some landowners from the project. In the Hekluskógar project in Iceland, some areas were excluded from the project because of farmers being concerned about continued use of grazing commons. In the Skjern River restoration project, negotiations with landowners and NGOs resulted in modifications of plans to protect migrating salmon and trout. In the Northern Great Plains restoration project in Canada, scientists were involved to deal with questions about seed origin, seed types, seed nativeness, and sowing practices. In the Green Belt forest restoration project, a dialogue with scientists resulted in establishment of control sites and specific studies on the impact of reindeer grazing on plant regeneration.

Step 2: Evaluation between planning and implementation

Many projects used meetings, workshops, and media to share information about the practical implementation and to receive feedback on the techniques and location of restoration and its anticipated outcome. For example, in the peatland restoration projects in eastern Finland (Green Belt LIFE) and Scotland (Caithness and Sutherland), feedback from landowners influenced the planning if restoration jeopardized the economic benefits from forestry or grazing on neighboring, private land. The restoration plans were then modified or restoration activities moved elsewhere. The example from the Vindel River LIFE restoration project shows that information and visits to restored sites stimulated landowners, who earlier had rejected restoration actions on their land, to change their decision. Restoration could thereafter be implemented on their land. Interestingly, even more radical practices than those originally suggested were then used because implementation practices had developed over years based on previous evaluations. On the other hand, restoration projects initiated at high governmental levels, such as parliamentary decisions, may restrict the flexibility of restoration plans as seen in the example from the Skjern River. Only minor adjustments were made following the mandatory environmental impact assessment after the initial project plan. Although the Dovre Mountains project has clear obligations to the Norwegian parliament, and the Norwegian Defense Estate Agency had been fully responsible for the project, both expert knowledge and stakeholder opinions were incorporated into the final implementation. In the Northern Great Plains grassland restoration project, scientific experts were partners with the National Park staff and collaborated on the technique and location of restoration, as well as evaluation of its effectiveness. Technical evaluation of whether the project was implemented as planned varied among projects. The Green Belt project applied similar procedures to the Canadian project to make sure that the size and number of restoration sites and the applied practices followed the restoration plan.

Step 3: Evaluation within implementation

Most projects used already established ("best-practice") restoration practices. However, because of evaluation during the implementation step ("learning by doing"), adjustments were also common. In the Northern Great Plains grassland restoration example, observations during implementation suggested a need to allow soil-seed contact by removing extant vegetation, which led to higher success of reintroduced plants. Improved scientific methods were also tested: in the Green Belt peatland restoration project, a new and more expensive method of wood removal was applied by the implementer (a researcher) without extra cost to the project owner. In cases of insufficient experience, possibilities for adjustments were incorporated into the implementation plan. For example, in the long-term Skjern River restoration project, tenders were made stepwise to incorporate initial experiences in later phases of implementation. Evaluations took place in the field or as regular meetings and included project owners, planners, and contractors. This also occurred in the Dovre Mountains where the project owner and experts regularly met with the machine operators in the field. This was also the case when public officers and farmers in the project Farmers Heal the Land discussed field methods. Such evaluations were often informal and produced limited documentation. The outcome of evaluation was seen as modifications on a practical level, e.g., in several projects where distribution of plants, turf size, selected type of gravel, and technical equipment used, led to changes in implementation. Large-scale modifications were also made, as in the Skjern River example where modifications in the planned movement of soil led to an enlargement of an already planned lake.

Step 4: Evaluation between implementation and monitoring

In this step practitioners passed information to the monitoring teams about the accomplished work and its location. Deviations from the original plan were highlighted so that monitoring could be conducted in the areas where it made most sense. For example, in the restoration of montane grassland in Scotland, maps showing which type of fence (sheep only, or sheep and rabbit) and their locations were passed on to the monitoring team. In the Green Belt forest restoration project, monitored sites had to be moved because of mistakes made in the placement of restoration. In the Vindel River, practitioners updated the monitoring team on changes in methods to facilitate monitoring. The bulk of information flow in this step went from the practitioners to the monitoring teams. However, the monitoring could also feed back to the practitioners, potentially resulting in direct modification of ongoing work on the site. This was the case at the alpine heathland restoration project in Dovre Mountains, and in the rangeland restoration project in Iceland, where there were clear avenues for informal dialogue between the practitioners and the people carrying out the monitoring. When the restoration work was conducted as part of an experiment, such as the montane grassland restoration in Scotland, the monitoring team had to communicate with the practitioners to ensure that the layout of the plots provided sufficient replication. Evaluation in this step was often ongoing throughout the project. There were also examples when monitoring started before implementation of the restoration to gather baseline data, e.g., in the Green Belt peatland and forest restoration projects. In these cases the implementation activities such as ditch-closing and logging were planned to avoid damaging the groundwater sampling wells and monitoring gear.

Step 5: Evaluation within monitoring

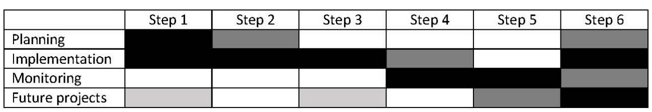
Formal monitoring usually started after the practical work was finished. Some exceptions were found, however, as in the Dovre Mountains alpine heathland restoration project where monitoring started four years before the full-scale restoration was implemented in order to support the project with relevant background information and allow "before and after" comparisons. In some cases, the chosen variables did not show much change. For example, very little biotic change was found in the Vindel River during the first two decades after restoration. To ensure that monitoring succeeded in detecting an extremely slow response, monitoring was continued using the same variables. In the montane grassland restoration project in Scotland, a similar situation was solved by adding 6 more monitoring years to the original 11. Long-term monitoring also allowed the documentation of restoration failure, e.g., the grassland restoration project in Canada in which native species were replaced by successional waves of exotic invaders over 18 years. To ensure that a lack of response was not caused by monitoring the wrong variables, additional variables were sometimes chosen for monitoring, but monitoring of the original variables was maintained. In the Canadian grassland restoration project, the unexpected flowering of prominent target species was quantified. In other cases, the restoration led to emergence of new microhabitat types, such as those in ditches following restoration of drained peatlands in Finland. In these cases, new plots were established in addition to the original ones in order not to miss any change in the restored site.

Step 6: Evaluation between monitoring and planning

Monitoring teams often had double roles in that they reported back to both restoration practitioners and planners. In both these cases, information could be evaluated (steps 4 and 6, respectively). An important part of the reports consisted of more or less standardized documentation of the project results. Reports to planners suggested modifications of the plans and project designs that could either be ignored, left for consideration in future projects, or assimilated in current projects. We found several examples of monitoring results being adopted in current and future projects. For instance, in the Vindel River, studies showed that water was not slowed down during high flows because of the lack of large elements such as big boulders and tree trunks. The large elements were consequently incorporated in the project and suggested to planners for inclusion in future projects. A similar example comes from the removal of military roads in the Dovre Mountains where monitoring provided hands-on advice on how to modify the plans, a modification that was also implemented. In the grassland restoration in Canada, monitoring showed that the original plan to eliminate nonnative plants was unrealistic, and the agreed compromise was to keep them but manage the land in such a way that they were kept at a lower abundance than before. In the Skjern River, monitoring led the project owners to adjust the boundaries of the restored site and to compensate the landowners economically. Monitoring also led to changed grazing strategies in the restored area. In the Finnish forest restoration and other similar forest restoration projects, monitoring showed that tree cutting was an inefficient method to initiate succession or bring back the desired threatened species and this information was used to make subsequent plans.

Our results indicate that evaluation could have an impact in all of the steps, but that the importance varied among steps (Fig. 2). Although the first four evaluation steps were most important for ongoing restoration projects, the last two evaluation steps were most likely to affect future projects.

Fig. 2. Potential of evaluation to cause changes in project planning, implementation, monitoring, and future projects. Black = high potential; Dark gray = moderate potential (modifies some but not all projects); Light gray = possible changes on rare occasions but lack of documentation (at least in the projects analyzed in the present study); White = changes are unlikely to happen. Evaluation steps are defined in the Introduction and in Table 1.



DISCUSSION

Our analysis clearly demonstrates that ecological restoration projects can include evaluation throughout the restoration process. In our 10 case studies, the three basic restoration phases, planning, implementation, and monitoring, all involved components of evaluation and reflection, within as well as between phases. Thus, we got a clear "yes" answer to our first question on whether the selected data set includes examples of evaluation at each of the six steps. Our case studies also demonstrated that evaluations can be formal as well as informal, and in many projects both kinds occurred. Formal evaluations were usually linked to mandatory processes such as environmental impact assessments, hearings or land-use planning, research and scientific publication, or strict protocols. Examples of informal evaluation included discussions and other exchange of information between actors involved in restoration, but also critical thinking by individual actors. No actor was formally excluded from the evaluation process, but the combinations of actors involved varied among phases and projects. In general, informal evaluations were poorly documented, if at all, but still built up important experiences and knowledge among the actors involved.

In many of the case studies, the informal evaluation processes also led to important modification of the restoration work. This means that also the second question on whether there are steps at which evaluation led to modification of projects can be answered "yes." In general, the large EU projects Green Belt LIFE in Finland and Vindel River LIFE in Sweden had more mandatory evaluation processes than the other projects, which is reasonable given that large projects are expensive and may affect many peoples' lives. This does not necessarily mean, however, that the evaluation is always satisfactory. For example, Morsing et al. (2013) analyzed 13 completed LIFE projects in Denmark and found that their evaluation was focused on ecosystem structures, which was not considered sufficient to assess the recovery of ecosystem processes. Measuring structures is often the key to evaluate processes because direct quantification of processes can be rather difficult, although not impossible (Muotka and Laasonen 2002, Ruiz-Jaén and Aide 2005). Ecosystem processes related to the nutrient cycling, such as decomposition and mineralization rates were in fact monitored in the Green Belt LIFE project (Tarvainen et al. 2013), but these evaluations were made using other sources than the EU funding. As the basic knowledge on the restoration impacts on the ecosystem structure is continuously increasing, restoration projects can direct more funding to the evaluation of ecosystem processes in the future.

Evaluations in the analyzed projects had three aims: (1) to assist the restoration process, (2) to judge the outcome of the restoration works, and (3) to gather information that could serve as a basis for deciding whether experiences from recent projects could be used in future projects. With respect to the outcome, evaluations could either identify which restoration projects had achieved their goals, or identify weaknesses that could lead to changes in one or more of the planning, implementation, and monitoring phases, for future projects. To fully evaluate the outcomes, all relevant variables, including the social ones, should be included. Barthélémy and Armani (2015) noted that social processes and local experiences are often ignored in restoration projects and Aronson et al. (2010) and Blignaut et al. (2013, 2014) found that the benefits of restoration for society were not given due attention. In most of our case studies, however, the social component was fairly well included in the projects. Information used in the process of planning evaluation is especially interesting to the public, because people tend to resist change, including changes wrought by restoration (Oreg 2003). However, although most projects dealt with social processes, these processes were seldom quantified. Instead, the data available for judging the success of projects were biotic in most of the case studies. This is a potential weakness because many studies have found that biotic variables exhibit a poor recovery and that an early judgement can lead to biased conclusions (Palmer et al. 2010, Nilsson et al. 2015). In such cases, it is likely that restoration actors will have to wait longer before they can draw any conclusions from the evaluation. Irrespective of the results of evaluations, their quality may vary considerably. For example, in an analysis of 62 European evaluation studies, Kleijn and Sutherland (2003) showed that many evaluations were too poorly designed to allow any conclusions about whether projects had reached their goals. To avoid such failures, well-designed, standardized protocols are needed (Palmer et al. 2005, Kurth and Schirmer 2014).

Our final question was about limitations to the evaluation of restoration. A major challenge with regard to evaluation is how it is documented and reported, if at all. It is true that very few restoration projects undergo formal evaluation (e.g., Kondolf and Micheli 1995, Bernhardt et al. 2005, Brooks and Lake 2007), but if they do, it usually results in some kind of written documentation or photographs. Our analysis corroborated this view. Most of the investigated projects included components of informal evaluation and these were rarely documented or reported, which means that lessons learned cannot fully benefit future projects unless they are properly communicated between the respective groups of restoration actors. Such communication between for example scientists who have generated knowledge and practitioners who are expected to apply it is an intricate task (Hulme 2014). In our analysis, however, we were able to uncover much informal evaluation simply because we had personal knowledge about the projects and expanded our knowledge by collecting more information from restoration actors involved. Even if restoration actors do not document or report their findings, results can still be preserved if there are interested end-users. This means that the results of some kinds of evaluation can be gleaned from end-users and the public by way of field visits, websites, media articles, teacher education, school visits, roadside interpretive displays, and museum exhibits. Such evaluations are also important to share with actors in future restoration projects.

We were also able to get access to hidden examples of documented evaluation. The fact that evaluations are documented does not necessarily mean that they are made public. If published, this may have been done in reports or other gray literature that is poorly accessible to the wider scientific community (Aradottir and Hagen 2013). To make dissemination of all documented information possible, it should ideally be archived in open, searchable databases.

Even if restoration projects undergo evaluation and result in published reports, we found it difficult to get a grasp of entire projects by reading the disseminated work from the 10 studied cases. Our analysis suggests that only the most “interesting” and “successful” outcomes of the different evaluation steps are widely disseminated to the public. This is a general issue that leads to underrepresentation of “failed” restoration projects in the literature (cf. Zedler 2007). The low acceptance rates of scientific journals, and the time required to prepare and submit a paper, discourage publication, especially of local and statistically nonsignificant results or of seemingly failed projects. Therefore, making project evaluations public is a major challenge.

Our case studies also provided examples of the importance of public education along-side evaluation. In the Vindel River restoration project landowners who were reluctant to restore their streams changed their minds after having seen the result of other restoration projects (Gardeström et al. 2013). In addition, it also suggests that confidence between restoration actors and landowners can be built if restoration projects are not rushed or imposed on people (cf. Bunn et al. 2010). Other examples of education include information about the role of ecological restoration and the importance of native biodiversity (Hulme 2006) and stricter controls on introductions of nonnative species (van Wilgen and Richardson 2014).

Another important challenge is the persistence of an evaluation result. Formal evaluations, if carried out, usually apply to monitoring results gathered in step 5. Generally, such evaluations are based on short-term monitoring datasets because most monitoring programs do not supply the resources necessary to await the long-term effects of restoration (Suding 2011, Nilsson et al. 2015). Evaluations based on restricted time periods may miss considerable amounts of information that, properly used, could have led to modification of the entire restoration process and hopefully better restoration practices in the future, i.e., adaptive management (Williams 2011). Instead, cookbook solutions (Hilderbrand et al. 2005, Fryirs and Brierley 2009), often nonoptimal, are likely to become overused. To solve this problem, a revised approach to funding and monitoring is required. An example of such an approach can be found in northern Sweden, where a court verdict over a disputed railway construction through a Natura 2000 area led to the funding of a 100-year monitoring program (Länsstyrelsen Västerbotten 2015). The objectives of this program are to evaluate the long-term effects of the railway and a number of compensation measures on the wildlife in the area, but also to manage the area so it can maintain its wildlife values. A special foundation board with representatives from landowners, NGOs, public authorities, and scientists is responsible for the management of the monitoring and evaluation and also makes sure that the collected information is stored and made available to interested users (Länsstyrelsen Västerbotten 2015).

We conclude that ecosystem restoration practices are developing, although slowly, because the actors involved evaluate and modify their practices throughout the restoration process. In the majority of cases, however, the evaluation is informal and not documented, meaning that lessons learned can only be forwarded if communicated among actors involved or if restoration is implemented by the same actor who developed an evaluation step. To speed up the effectiveness of ecological restoration, we recommend that actors reflect about their practices, document their experiences and spread the word about their findings, both successes and failures. In addition to more traditional ways of interaction, the modern digital world offers numerous possibilities for sharing the lessons learned. Another important development would be an economic analysis of the cost-efficiency of monitoring and evaluation. Increased knowledge in this respect has the potential to foster a better understanding of the significance of budgeting for evaluation in every restoration project.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/8289

Acknowledgments:

This study was conducted under the project EvRest - Evaluation of Ecological Restoration in the North, funded by the Nordic Council of Ministers. We thank three reviewers for valuable comments.

LITERATURE CITED

Allen, C. D., M. Savage, D. A. Falk, K. F. Suckling, T. W. Swetnam, T. Schulke, P. B. Stacey, P. Morgan, M. Hoffman, and J. T. Klingel. 2002. Ecological restoration of southwestern ponderosa pine ecosystems: a broad perspective. *Ecological Applications* 12:1418-1433. http://dx.doi.org/10.1890/1051-0761(2002)012[1418:EROSPP]2.0.CO;2

Aradottir, A. L. 2007. Restoration of birch and willow woodland on eroded areas. Pages 67-74 *in* G. Halldorsson, E. S. Oddsdottir, and O. Eggertsson, editors. *Effects of afforestation on ecosystems,* *landscape and rural development*. TemaNord 2007:508, Reykholt, Iceland, June 18-22, 2005. http://www.norden.org/en/publications/publikationer/2007-508/

Aradottir, A. L., and D. Hagen. 2013. Ecological restoration: approaches and impacts on vegetation, soils and society. *Advances in Agronomy* 120:173-222. http://dx.doi.org/10.1016/B978-0-12-407686-0.00003-8

Aradóttir, Á. L., T. Petursdottir, G. Halldorsson, K. Svavarsdottir, and O. Arnalds. 2013. Drivers of ecological restoration: lessons from a century of restoration in Iceland. *Ecology and Society* 18(4):33. http://dx.doi.org/10.5751/ES-05946-180433

Aradóttir, Á. L., K. Svavarsdóttir, Þ. H. Jónsson, and G. Guðbergsson. 2000. Carbon accumulation in vegetation and soils by reclamation of degraded areas. *Icelandic Agricultural Sciences* 13:99-113.

Arnalds, A. 2005. Approaches to landcare—a century of soil conservation in Iceland. *Land Degradation and Development* 16:113-125. http://dx.doi.org/10.1002/ldr.665

Aronson, J., J. N. Blignaut, S. J. Milton, D. Le Maitre, K. J. Esler, A. Limouzin, C. Fontaine, M. P. de Wit, W. Mugido, P. Prinsloo, L. van der Elst, and N. Lederer. 2010. Are socioeconomic benefits of restoration adequately quantified? A meta-analysis of recent papers (2000-2008) in *Restoration Ecology* and 12 other scientific journals. *Restoration Ecology* 18:143-154. http://dx.doi.org/10.1111/j.1526-100X.2009.00638.x

Bakker, J. D., S. D. Wilson, J. M. Christian, X. Li, L. G. Ambrose, and J. Waddington. 2003. Contingency of grassland restoration on year, site, and competition from introduced grasses. *Ecological Applications* 13:137-153. http://dx.doi.org/10.1890/1051-0761(2003)013[0137:COGROY]2.0.CO;2

Barral, M. P., J. M. R. Benayas, P. Meli, and N. O. Maceira. 2015. Quantifying the impacts of ecological restoration on biodiversity and ecosystem services in agroecosystems: a global meta-analysis. *Agriculture Ecosystems and Environment* 202:223-231. http://dx.doi.org/10.1016/j.agee.2015.01.009

Barthélémy, C., and G. Armani. 2015. A comparison of social processes at three sites of the French Rhône River subjected to ecological restoration. *Freshwater Biology* 60:1208-1220. http://dx.doi.org/10.1111/fwb.12531

Bell, R. M., and J. Kolb. 2013. Various alteration stages in the Nalunaq gold deposit, south Greenland. *Mineral Deposit Research for a High-Tech World* 1-4:1093-1096.

Berglund, B., L. Hallgren, and Á. L. Aradóttir. 2013. Cultivating communication: participatory approaches in land restoration in Iceland. *Ecology and Society* 18(2):35. http://dx.doi.org/10.5751/ES-05516-180235

Bernhardt, E. S., and M. A. Palmer. 2011. River restoration: the fuzzy logic of repairing reaches to reverse catchment scale degradation. *Ecological Applications* 21:1926-1931. http://dx.doi.org/10.1890/10-1574.1

Bernhardt, E. S., M. A. Palmer, J. D. Allan, G. Alexander, K. Barnas, S. Brooks, J. Carr, C. Dahm, J. Follstad-Shah, D. Galat, S. Gloss, P. Goodwin, D. Hart, B. Hassett, R. Jenkinson, S. Katz, G. M. Kondolf, P. S. Lake, R. Lave, J. L. Meyer, T. K. O'Donnell, L. Pagano, B. Powell, and E. Sudduth. 2005. Synthesizing U.S. river restoration. *Science* 308:636-637. http://dx.doi.org/10.1126/science.1109769

Blignaut, J., J. Aronson, and M. De Wit. 2014. The economics of restoration: looking back and leaping forward. *Annals of the New York Academy of Sciences* 1322:35-47. http://dx.doi.org/10.1111/nyas.12451

Blignaut, J., K. J. Esler, M. P. de Wit, D. Le Maitre, S. J. Milton, and J. Aronson. 2013. Establishing the links between economic development and the restoration of natural capital. *Current Opinion in Environmental Sustainability* 5:94-101. http://dx.doi.org/10.1016/j.cosust.2012.12.003

Brooks, S. S., and P. S. Lake. 2007. River restoration in Victoria, Australia: change is in the wind, and none too soon. *Restoration Ecology* 15:584-591. http://dx.doi.org/10.1111/j.1526-100X.2007.00253.x

Brown, E. C., and R. V. Birnie. 2012. *Trotternish Ridge SAC: long-term monitoring of vegetation and erosion, historic change and management recommendations*. Scottish Natural Heritage Commissioned Report No. 505, Inverness, UK. http://www.snh.org.uk/pdfs/publications/commissioned_reports/505.pdf

Bunn, S. E., E. G. Abal, M. J. Smith, S. C. Choy, C. S. Fellows, B. D. Harch, M. J. Kennard, and F. Sheldon. 2010. Integration of science and monitoring of river ecosystem health to guide investments in catchment protection and rehabilitation. *Freshwater Biology* 55:223-240. http://dx.doi.org/10.1111/j.1365-2427.2009.02375.x

Campbell, D., and J. Bergeron. 2012. Natural revegetation of winter roads on peatlands in the Hudson Bay lowland, Canada. *Arctic, Antarctic, and Alpine Research* 44:155-163. http://dx.doi.org/10.1657/1938-4246-44.2.155

Dominy, S. C., E. J. Sides, O. Dahl, and I. M. Platten. 2006. Estimation and exploitation in an underground narrow vein gold operation: Nalunaq Mine, Greenland. *Australasian Institute of Mining and Metallurgy Publication Series* 2006:29-44.

Elmarsdottir, A., A. L. Aradottir, and M. J. Trlica. 2003. Microsite availability and establishment of native species on degraded and reclaimed sites. *Journal of Applied Ecology* 40:815-823. http://dx.doi.org/10.1046/j.1365-2664.2003.00848.x

Erwin, K. L. 2009. Wetlands and global climate change: the role of wetland restoration in a changing world. *Wetlands Ecology and Management* 17:71-84. http://dx.doi.org/10.1007/s11273-008-9119-1

Forbes, B. C., and J. D. McKendrick. 2002. Polar tundra. Pages 355-375 *in* M. Perrow and A. J. Davy, editors. *Handbook of ecological restoration*. Cambridge University Press, Cambridge, UK.

Fryirs, K., and G. J. Brierley. 2009. Naturalness and place in river rehabilitation. *Ecology and Society* 14(1):20. [online] URL: http://www.ecologyandsociety.org/vol14/iss1/art20/

Gardeström, J., D. Holmqvist, L. E. Polvi, and C. Nilsson. 2013. Demonstration restoration measures in tributaries of the Vindel river catchment. *Ecology and Society* 18(3):8. http://dx.doi.org/10.5751/ES-05609-180308

Gunderson, L., and S. S. Light. 2006. Adaptive management and adaptive governance in the Everglades ecosystem. *Policy Science* 39:323-334. http://dx.doi.org/10.1007/s11077-006-9027-2

Hagen, D., and M. Evju. 2013. Using short-term monitoring data to achieve goals in a large-scale restoration. *Ecology and Society* 18(3):29. http://dx.doi.org/10.5751/ES-05769-180329

Hagen, D., K. Svavarsdottir, C. Nilsson, A. K. Tolvanen, K. Raulund-Rasmussen, Á. L. Aradóttir, A. Fosaa, and G. Halldorsson. 2013. Ecological and social dimensions of ecosystem restoration in the Nordic countries. *Ecology and Society* 18(4):34. http://dx.doi.org/10.5751/ES-05891-180434

Hägglund, R., A.-M. Hekkala, J. Hjältén, and A. Tolvanen. 2015. Positive effects of ecological restoration on rare and threatened flat bugs (Heteroptera: Aradidae). *Journal of Insect Conservation* 19:1089-1099. http://dx.doi.org/10.1007/s10841-015-9824-z

Halldórsson, G., Á. L. Aradóttir, A. M. Fosaa, D. Hagen, C. Nilsson, K. Raulund-Rasmussen, A. B. Skrindo, K. Svavarsdóttir, and A. Tolvanen. 2012. *ReNo: restoration of damaged ecosystems in the Nordic Countries*. Nordic Council of Ministers, Copenhagen, Denmark.

Hasselquist, E. M., C. Nilsson, J. Hjältén, D. Jørgensen, L. Lind, and L. E. Polvi. 2015. Time for recovery of riparian plants in restored northern Swedish streams: a chronosequence study. *Ecological Applications* 25:1373-1389. http://dx.doi.org/10.1890/14-1102.1

Hekkala, A.-M., M.-L. Päätalo, O. Tarvainen, and A. Tolvanen. 2014*a*. Restoration of young forests in eastern Finland: benefits for saproxylic beetles (Coleoptera). *Restoration Ecology* 22:151-159. http://dx.doi.org/10.1111/rec.12050

Hekkala, A.-M., O. Tarvainen, and A. Tolvanen. 2014*b*. Dynamics of understory vegetation after restoration of natural characteristics in the boreal forests in Finland. *Forest Ecology and Management* 330:55-66. http://dx.doi.org/10.1016/j.foreco.2014.07.001

Helfield, J. M., S. J. Capon, C. Nilsson, R. Jansson, and D. Palm. 2007. Restoration of rivers used for timber floating: effects on riparian plant diversity. *Ecological Applications* 17:840-851. http://dx.doi.org/10.1890/06-0343

Hewison, R. L., E. C. Brown, R. V. Birnie, and J. Alexander. 2016. *Continued long-term monitoring of calcareous grasslands and erosion within the Trotternish Ridge SAC*. Scottish Natural Heritage Commissioned Report. Inverness, UK, in press.

Hilderbrand, R. H., A. C. Watts, and A. M. Randle. 2005. The myths of restoration ecology. *Ecology and Society* 10(1):19. [online] URL: http://www.ecologyandsociety.org/vol10/iss1/art19/

Hobbs, R. J., and D. A. Norton. 1996. Towards a conceptual framework for restoration ecology. *Restoration Ecology* 4:93-110. http://dx.doi.org/10.1111/j.1526-100X.1996.tb00112.x

Hughes, F. M. R., P. A. Stroh, W. M. Adams, K. J. Kirby, J. O. Mountford, and S. Warrington. 2011. Monitoring and evaluating large-scale, 'open-ended' habitat creation projects: a journey rather than a destination. *Journal for Nature Conservation* 19:245-253. http://dx.doi.org/10.1016/j.jnc.2011.02.003

Hulme, P. E. 2006. Beyond control: wider implications for the management of biological invasions. *Journal of Applied Ecology* 43:835-847. http://dx.doi.org/10.1111/j.1365-2664.2006.01227.x

Hulme, P. E. 2014. Bridging the knowing-doing gap: know-who, know-what, know-why, know-how and know-when. *Journal of Applied Ecology* 51:1131-1136. http://dx.doi.org/10.1111/1365-2664.12321

Jungwirth, M., S. Muhar, and S. Schmutz. 2002. Re-establishing and assessing ecological integrity in riverine landscapes. *Freshwater Biology* 47:867-887. http://dx.doi.org/10.1046/j.1365-2427.2002.00914.x

Kleijn, D., and W. J. Sutherland. 2003. How effective are European agri-environment schemes in conserving and promoting biodiversity? *Journal of Applied Ecology* 40:947-969. http://dx.doi.org/10.1111/j.1365-2664.2003.00868.x

Kondolf, G. M., and E. R. Micheli. 1995. Evaluating stream restoration projects. *Environmental Management* 19:1-15. http://dx.doi.org/10.1007/BF02471999

Kurth, A.-M., and M. Schirmer. 2014. Thirty years of river restoration in Switzerland: implemented measures and lessons learned. *Environmental Earth Sciences* 72:2065-2079. http://dx.doi.org/10.1007/s12665-014-3115-y

Laine, A. M., M. Leppälä, O. Tarvainen, M.-L. Päätalo, R. Seppänen, and A. Tolvanen. 2011. Restoration of managed pine fens: effect on hydrology and vegetation. *Applied Vegetation Science* 14:340-349. http://dx.doi.org/10.1111/j.1654-109X.2011.01123.x

Lal, R. 2004. Soil carbon sequestration to mitigate climate change. *Geoderma* 123:1-22. http://dx.doi.org/10.1016/j.geoderma.2004.01.032

Länsstyrelsen Västerbotten. 2015. *Stiftelsen naturvård vid nedre Umeälven.* Västerbotten, Sweden. [online] URL: http://www.lansstyrelsen.se/vasterbotten/Sv/naringsliv-och-foreningar/stiftelser/stiftelsen-naturvard-vid-nedre-umealven/Pages/default.aspx

Le Houerou, H. N. 2000. Restoration and rehabilitation of arid and semiarid Mediterranean ecosystems in North Africa and west Asia: a review. *Arid Soil Research and Rehabilitation* 14:3-14. http://dx.doi.org/10.1080/089030600263139

Loftin, M. K. 2014. Truths and governance for adaptive management. *Ecology and Society* 19(2):21. http://dx.doi.org/10.5751/ES-06353-190221

Lunt, P., T. Allot, P. Anderson, M. Buckler, A. Coupar, P. Jones, J. Labadz, and P. Worrall. 2010. *Peatland restoration*. Scientific Review commissioned by IUCN UK Peatland Programme Commission of Inquiry into Peatland Restoration, Edinburgh, UK. [online] URL: http://www.iucn-uk-peatlandprogramme.org/sites/www.iucn-uk-peatlandprogramme.org/files/Review%20Peatland%20Restoration,%20June%202011%20Final.pdf

Martinsen, O.-E., and D. Hagen. 2010. Tilbakeføring av Hjerkinn skytefelt til sivile formål (Hjerkinn PRO) [Restoration of Hjerkinn firing range into nature conservation areas (Hjerkinn PRO)]. Pages 35-37 *in* D. Hagen and A. B. Skrindo, editors. *Restaurering av natur i Norge-et innblikk i fagfeltet, fagmiljøet og pågående aktivitet [Restoration of nature in Norway-a glimpse into the thematic field, professional institutions and ongoing activity].*

NINA Temahefte 42, Norwegian Institute for Nature Research, Trondheim, Norway.

Ministry of Defence. 1998. *Regionalt skyte- og øvingsfelt for Forsvarets avdelinger på Østlandet - Regionfelt Østlandet.* St.meld. nr. 11 (1998-99). White paper, Ministry of Defence, Oslo, Norway.

Morandi, B., H. Piégay, N. Lamoroux, and L. Vaudor. 2014. How is success or failure in river restoration projects evaluated? Feedback from French restoration projects. *Journal of Environmental Management* 137:178-188. http://dx.doi.org/10.1016/j.jenvman.2014.02.010

Morsing, J., S. I. Frandsen, H. Vejre, and K. Raulund-Rasmussen. 2013. Do the principles of ecological restoration cover EU LIFE nature cofunded projects in Denmark? *Ecology and Society* 18 (4):15. [online] URL: http://www.ecologyandsociety.org/vol18/iss4/art15/

Muotka, T., and P. Laasonen. 2002. Ecosystem recovery in restored headwater streams: the role of enhanced leaf retention. *Journal of Applied Ecology* 39:145-156. http://dx.doi.org/10.1046/j.1365-2664.2002.00698.x

Nilsson, C., L. E. Polvi, J. Gardeström, E. M. Hasselquist, L. Lind, and J. M. Sarneel. 2015. Riparian and in-stream restoration of boreal streams and rivers: success or failure? *Ecohydrology* 8:753-764. http://dx.doi.org/10.1002/eco.1480

Novacek, M. J., and E. E. Cleland. 2001. The current biodiversity extinction event: scenarios for mitigation and recovery. *Proceedings of the National Academy of Sciences of the United States of America* 98:5466-5470. http://dx.doi.org/10.1073/pnas.091093698

Oreg, S. 2003. Resistance to change: developing an individual differences measure. *Journal of Applied Psychology* 88:680-693. http://dx.doi.org/10.1037/0021-9010.88.4.680

Óskarsson, H. 2009*a*. Hekluskógar: endurheimt birkiskóga í nágrenni Heklu [Heklaforest: restoration of birch woodlands in the vicinity of the Hekla volcano]. *Fræðaþing landbúnaðarins* 6:286-290.

Óskarsson, H. 2009*b*. Hekluskogar: Islands største reetablering af birkeskove *[Heklaforest: Iceland's largest restoration of natural birch woodlands]*. *Skoven* 41(1):35-39.

Óskarsson, H. 2011. Hekluskógar [Heklaforest. Pages 71-74 in Á. L. Aradóttir and G. Halldórsson, editors. *Vistheimt á Íslandi* [*Ecological restoration in Iceland*]. Agricultural University of Iceland and Soil Conservation Service of Iceland, Reykjavík, Iceland.

Palm, D., E. Brännäs, F. Lepori, K. Nilsson, and S. Stridsman. 2007. The influence of spawning habitat restoration on juvenile brown trout (*Salmo trutta*) density. *Canadian Journal of Fisheries and Aquatic Sciences* 64:509-515. http://dx.doi.org/10.1139/f07-027

Palmer, M. A., E. S. Bernhardt, J. D. Allan, P. S. Lake, G. Alexander, S. Brooks, J. Carr, S. Clayton, C. N. Dahm, J. F. Shah, D. L. Galat, S. G. Loss, P. Goodwin, D. D. Hart, B. Hassett, R. Jenkinson, G. M. Kondolf, R. Lave, J. L. Meyer, T. K. O'Donnell, L. Pagano, and E. Sudduth. 2005. Standards for ecologically successful river restoration. *Journal of Applied Ecology* 42:208-217. http://dx.doi.org/10.1111/j.1365-2664.2005.01004.x

Palmer, M. A., H. L. Menninger, and E. Bernhardt. 2010. River restoration, habitat heterogeneity and biodiversity: a failure of theory or practice? *Freshwater Biology* 55(Suppl. 1):205-222. http://dx.doi.org/10.1111/j.1365-2427.2009.02372.x

Pander, J., and J. Geist. 2013. Ecological indicators for stream restoration success. *Ecological Indicators* 30:106-118. http://dx.doi.org/10.1016/j.ecolind.2013.01.039

Pedersen, A. B. 2010. The fight over Danish nature: explaining policy network change and policy change. *Public Administration* 88:346-363. http://dx.doi.org/10.1111/j.1467-9299.2009.01790.x

Pedersen, M. L., J. M. Andersen, K. Nielsen, and M. Linnemann. 2007*a*. Restoration of Skjern River and its valley: project description and general ecological changes in the project area. *Ecological Engineering* 30:131-144. http://dx.doi.org/10.1016/j.ecoleng.2006.06.009

Pedersen, M. L., N. Friberg, J. Skriver, A. Baattrup-Pedersen, and S. E. Larsen. 2007*b*. Restoration of Skjern River and its valley: short-term effects on river habitats, macrophytes and macroinvertebrates. *Ecological Engineering* 30:145-156. http://dx.doi.org/10.1016/j.ecoleng.2006.08.009

Petursdottir, T., O. Arnalds, S. Baker, L. Montanarella, and A. L. Aradottir. 2013*a*. A social-ecological system approach to analyze stakeholders' interactions within a large-scale rangeland restoration program. *Ecology and Society* 18(2):29. http://dx.doi.org/10.5751/ES-05399-180229

Petursdottir, T., A. L. Aradottir, and K. Benediktsson. 2013*b*. An evaluation of the short-term progress of restoration combining ecological assessment and public perception. *Restoration Ecology* 21:75-85. http://dx.doi.org/10.1111/j.1526-100X.2011.00855.x

Polvi, L. E., C. Nilsson, and E. M. Hasselquist. 2014. Potential and actual geomorphic complexity of restored headwater streams in northern Sweden. *Geomorphology* 210:98-118. http://dx.doi.org/10.1016/j.geomorph.2013.12.025

Ruiz-Jaén, M. C., and T. M. Aide. 2005. Vegetation structure, species diversity, and ecosystem processes as measures of restoration success. *Forest Ecology and Management* 218:159-173. http://dx.doi.org/10.1016/j.foreco.2005.07.008

Schmidt, G. 2000. Bændur græða landið: viðhorf bænda [Farmers heal the land: farmers' perspective]. *Ráðunautafundur* 2000:93-98.

Schmutz, S., H. Kremser, A. Melcher, M. Jungwirth, S. Muhar, H. Waidbacher, and G. Zauner. 2014. Ecological effects of rehabilitation measures at the Austrian Danube: a meta-analysis of fish assemblages. *Hydrobiologia* 729:49-60. http://dx.doi.org/10.1007/s10750-013-1511-z

Similä, M., K. Aapala, and J. Penttinen, editors. 2014. *Ecological restoration of drained peatlands: best practices from Finland*. Metsähallitus Natural Heritage Services and Finnish Environment Institute, Vantaa, Finland.

Similä, M., and K. Junninen, editors. 2012. *Ecological restoration and management in boreal forests: best practices from Finland*.

Metsähallitus Natural Heritage Services, Vantaa, Finland. [online] URL: http://julkaisut.metsa.fi/assets/pdf/lp/Muut/ecological-restoration.pdf

Society for Ecological Restoration (SER). 2004. *SER International primer on ecological restoration*. Society for Ecological Restoration, Science & Policy Working Group, Washington, D.C., USA. http://ser.org/resources/resources-detail-view/ser-international-primer-on-ecological-restoration

Suding, K. N. 2011. Toward an era of restoration in ecology: successes, failures, and opportunities ahead. *Annual Review of Ecology, Evolution, and Systematics* 42:465-487. http://dx.doi.org/10.1146/annurev-ecolsys-102710-145115

Tarvainen, O., A. M. Laine, M. Peltonen, and A. Tolvanen. 2013. Mineralization and decomposition rates in restored pine fens. *Restoration Ecology* 21:592-599. http://dx.doi.org/10.1111/j.1526-100X.2012.00930.x

Tarvainen, O., and A. Tolvanen. 2015. Healing the wounds in the landscape—reclaiming gravel roads in conservation areas. *Environmental Science and Pollution Research* 1-13. http://dx.doi.org/10.1007/s11356-015-5341-6

Tischew, S., A. Baasch, M. K. Conrad, and A. Kirmer. 2010. Evaluating restoration success of frequently implemented compensation measures: results and demands for control procedures. *Restoration Ecology* 18:467-480. http://dx.doi.org/10.1111/j.1526-100X.2008.00462.x

van Wilgen, B. W., and D. M. Richardson. 2014. Challenges and trade-offs in the management of invasive alien trees. *Biological Invasions* 16:721-734. http://dx.doi.org/10.1007/s10530-013-0615-8

Williams, B. K. 2011. Adaptive management of natural resources—framework and issues. *Journal of Environmental Management* 92:1346-1353. http://dx.doi.org/10.1016/j.jenvman.2010.10.041

Wilson, S. D., and B. D. Pinno. 2013. Environmentally-contingent behaviour of invasive plants as drivers or passengers. *Oikos* 122:129-135. http://dx.doi.org/10.1111/j.1600-0706.2012.20673.x

Wortley, L., J.-M. Hero, and M. Howes. 2013. Evaluating ecological restoration success: a review of the literature. *Restoration Ecology* 21:537-543. http://dx.doi.org/10.1111/rec.12028

Zedler, J. B. 2007. Success: an unclear, subjective descriptor of restoration outcomes. *Ecological Restoration* 25:162-168. http://dx.doi.org/10.3368/er.25.3.162

Zedler, J. B., and J. C. Callaway. 2000. Evaluating the progress of engineered tidal wetlands. *Ecological Engineering* 15:211-225. http://dx.doi.org/10.1016/S0925-8574(00)00077-X

Appendix 1. Identified evaluation steps in major ecological restoration projects in the northern hemisphere.

Habitat restored and objectives	Identity of restoration project	Step 1 Within planning	Step 2 Between planning and implementation	Step 3 Within implementation	Step 4 Between implementation and monitoring	Step 5 Within monitoring	Step 6 Between monitoring and planning	References
Alpine heathland: removal of roads, military infrastructure, explosives and pollutants, restoring landscape structures and vegetation	Dovre Mountain, Norway	Interaction between Norwegian Defence Estates Agency (NDEA) and experts during the initial planning process resulting in more specific plans	NDEA planned and operated the project, and met with authorities, municipalities, tourist companies and hunters. NDEA evaluated the implementation and the outcome was used for further planning of subsequent project phases	Methods based on previous experiences. Collaboration between the project owner, ecologists and contractors led to some modification of procedures and logistic adjustment for large-scale application	Monitoring results reported back to people responsible for the implementation (ecologists, machine drivers, project owner) resulting in minor modifications and adjustments on site	Monitoring established as a pilot project 4 years before restoration. Vegetation data gave feedback on restoration methods (in particular the use of turfs, seeds and fertilizer). Data integrated into steps 3 and 4	The project owner posted annual reports on the web and distributed newsletters. Scientists reported on websites and conferences. Modifications were proposed to project owner. The cooperation procedure applied to related projects, e.g., hydropower and road construction	Martinsen and Hagen 2010, Hagen and Evju 2013, Forsvarsbygg 2015
Alpine heathland: removal of structures on a former mine site	Nalunaq gold mine, Greenland	Evaluation of clean-up and restoration plans between the mining company and central authorities	Stakeholder meetings and public hearings processing original and revised documents. The Environmental Impact Assessment was revised when production procedures were changed after 2009	It was decided not to use non-native seeds or plants to avoid unnatural conditions and invasive plants; therefore only barren land was left to be colonized by local plants	Informal but good communication and support were supplied to the monitoring team from the mining staff at Nalunaq	Ten monitoring reports produced, evaluating elements in aquatic and terrestrial environments. Monitoring will continue at least 3 years after the closure and was planned to take place during 2014–2016	Monitoring program evaluated and changed due to changes in mining techniques, i.e., emphasizing cyanide after 2009. Based on monitoring results it was possible to change demands towards the mining company	Dominy et al. 2006, Bell and Kolb 2013
Birch woodland: reforestation to enhance resilience to ash deposition	Hekluskógar, Iceland	Meetings with farmers and other stakeholders, presenting project ideas. Some areas excluded from the project due to farmers' concern about continued use of grazing commons	Project implementation discussed in a stakeholder group and with a wider audience, resulting in amendments of plans	Internal follow-up of implementation, mostly regarding planting of seedlings by contractors and landowners and other practicalities. This often led to adjustments of implementation	Landowners, contractors and other practitioners reported planting and revegetation activities to project manager. Monitoring results provided feedback to implementation	Original plans included regular monitoring of ecosystem development and assessment of socio-economic impact. Lack of funding restricted monitoring to seedling survival	Simple annual reports posted on project website, and project information reported at conferences together with monitoring results. Plans adapted based on monitoring results if needed	Aradottir 2007, Óskarsson 2009 a, b, 2011, Berglund et al. 2013, Hunziker et al. 2014. Hekluskógar 2015.
Rangeland:	Farmers Heal the	Interaction between	SCSI district officers	Individual farmers	During annual or	The annual, subjective	Next year's work	Schmidt 2000,

revegetating eroded areas by adding seeds, fertilizer and mulch	Land, Iceland	the Soil Conservation Service of Iceland (SCSI) and farmers during the initial planning process resulting in an adjusted approach	discussed and adjusted restoration plans based on farmers' feedback. SCSI district officers also evaluated whether activities were implemented as planned	adjusted their methods when needed due to practical restrictions. SCSI district officers and farmers discussed and sometimes modified methods	biannual visits farmers informed SCSI district officers about their restoration interventions, making revisions of subsequent interventions possible	assessment is informal and limited documentation is produced. This has been identified as too weak, and currently objective evaluation methods are being developed and tested	based on outcome of assessment. Results of questionnaires and informal interviews with participants have influenced project management	Elmarsdottir et al. 2003, Arnalds 2005, Berglund et al. 2013, Petursdottir et al. 2013a, b
Forest: burning, storm simulation, and cutting or wounding trees	Green Belt LIFE, Finland	Plans adapted after field conditions and research needs. Impact of reindeer grazing on plant regeneration included in the planning	Planners, practitioners and scientists discussed practicalities. Meetings for local people informed about restoration. Fire brigades and border patrols were informed about burnings. Technical evaluation carried out according to EU-LIFE standards	Established restoration methods applied by the coordinator and the researchers. Burning needed instant evaluation as it depends on weather conditions and could be implemented only during a short time frame	Location of monitoring gear conveyed to practitioners to avoid damage during implementation. For practical reasons, such as space requirements for burning, or mistakes made by the harvester in the tree cutting sites, control and restoration monitoring sites had sometimes to be moved	Different variables measured in different years, e.g., burning impact on trees not seen until after several years, but for the ground it was the opposite. Monitoring focused on species thought to respond to restoration. Research plots established to monitor new mineral soil patches after storm simulation	Scientists made results available through meetings, seminars, and discussions in the Finnish Restoration Board. Modifications proposed by scientists could not be applied to this project, but have been considered for later restoration projects	Similä and Junninen 2012; Hekkala et al. 2014a, b
Grassland: decreasing cover of invasive plants and reintroducing native species	Northern Great Plains, Canada	Interested landowners or government agencies were chosen as partners. Funds including evaluation were raised	Planners and practitioners discussed feasibility of plans with respect to site accessibility, required personnel, and available machines and methods	Methods were adjusted based on field experience, e.g., increasing soil–seed contact by removing extant vegetation improved the outcome of restoration	This step provided a chance to add variables based on field work, e.g., incorporate later ideas about nutrients or soil water by measuring their availabilities	Unexpected responses could be incorporated, e.g., counting flowering individuals of prominent target species	Discussion with stakeholders at special seminars and other practitioners at more general restoration conferences	Heidinga and Wilson 2002, Ambrose and Wilson 2003, Bakker et al. 2003, Wilson and Pärtel 2003, Bakker and Wilson 2004, Wilson et al. 2004, MacDougall et al. 2008, Wilson and Pinno 2013
Montane grassland: removal or reduction in grazing to favor grass cover and stop erosion	Trotternish, Skye, Scotland	Interaction between the Scottish Government, landowners and scientists during the initial planning process resulted in adjustments of	Planners and landowners discussed the restoration plan. Input from farmers determined location and maintenance of fences	Methods involved two types of fences, excluding sheep and rabbits or just sheep. The project was like a trial, and monitoring was evaluated, but not	Information about exclosures, treatments, sheep numbers and control plots were communicated to the monitoring team	Vegetation found to be slow to recover (11 years), so monitoring project was extended by six more years	Results made available to Scottish Natural Heritage. Possible influence of climate change and social economic changes with reduction in sheep due to aging of	Hewison et al. 2016

		approach		implementation			crofters and changes in agri-environmental schemes	
Peatland: removal of redundant trees and blocking of ditches	Green Belt LIFE, Finland	Plans adapted to site conditions and, as far as possible, to research needs	Planners, practitioners and scientists discussed project practicalities. Meetings with local people informed about restoration actions. Technical evaluation carried out according to EU-LIFE standards	Established restoration methods applied by the coordinating organization. Whole tree cutting introduced and carried out by the researchers interested in the method	Location of groundwater wells for monitoring purposes conveyed to practitioners to avoid damage during tree harvest, blocking of ditches and placement of logging residue during project implementation	Monitoring established to respond to spatial questions in future even though there was no spatial expert in the monitoring group. New research plots established in restored ditches, as they served as new habitat types not existing before restoration	Scientists made results available through meetings, seminars and discussions in the Finnish Restoration Board. Modifications discussed for later projects. Practical reasons hindered whole-tree harvesting although monitoring indicated it to be more effective than current stem harvest	Laine et al. 2011, Tarvainen et al. 2013, Similä and Aapala 2014
Peatland: blocking of ditches	Caithness and Sutherland, Scotland	Landowners, scientists and conservationists collaborated to agree on plans and find funding sources. During preparation of a management strategy, also practitioners were involved	Planners and landowners discussed location and extent of restoration sites, restoration methods, and potential impacts of water level rise. Restoration plan changed when needed	No formal but probably unconscious evaluation during implementation, e.g., to check if drains were successfully blocked	Information of what drains were blocked where and what management was carried out was compared to original plans and communicated to monitoring teams	Evaluation mainly done post restoration	Lack of long-term monitoring and lack of baseline data were major concerns	Lunt et al. 2010, Life peatlands project 2015t
River: removal of channelization structures and meadow drainage	Skjern River, Denmark	Landowners, NGOs and a stakeholder advisory committee were involved. Modifications were made, e.g., it was decided not to lead the river flow through a lake to protect migrating salmon and trout from predatory pike	An Environmental Impact Assessment was made and a construction law was adapted in Parliament. Public hearings gave input to work description, including technical evaluation. The advisory committee gave input and minor modifications were made	Tenders were requested in two steps, making changes possible in the second step. A soil movement program was modified and a planned lake was enlarged. Artificial grass mixtures were seeded to increase grass productivity and promote domestic cattle grazing contracts	A short term monitoring program began right after the construction work. Any important changes compared to the original plans are not known	Monitoring began right after construction works. Monitoring programs and assessments were set-up to evaluate project outcomes. A LIFE project aiming at improving the grassland-habitats was initiated. This could not be fully accomplished due to some areas being too wet. EU accepted this deviation	Monitoring, surveys and analyses led to scientific papers on project outcomes. Project boundaries adjusted due to wetness in nearby land and landowners compensated. Grazing strategies modified. Parts of project area set aside for open-ended succession. Conflicts among stakeholders continually addressed	Pedersen et al. 2007a, b, 2010, 2014, Feld et al. 2011

River: removal of timber-floating structures, creation of fish spawning beds and diversification of channel morphology	Vindel River LIFE, Sweden	Restoration plans adapted to landowner reactions: planners started working with the most cooperative ones, leaving recalcitrant landowners to later	Planners and practitioners discussed plans with respect to site accessibility, personnel, machines and methods. Plans presented for landowners. Technical evaluation carried out according to EU-LIFE standards	Methods developed over years, e.g., methods for applying coarse sediment and large wood into channels and for constructing fish spawning beds. Methods modified based on gained insights Discussions in the field with contractors, planners and scientists	Practitioners updated scientists on performed actions to facilitate monitoring. Scientists proposed modifications to implementation, e.g., that available sediment was not coarse enough for recreating channel structures	Fish populations and riparian vegetation monitored. Biotic responses found to be slow or absent. Biotic monitoring methods modified and extended to account for this slow response	Scientists made results available through websites and conference presentations. Modifications proposed by scientists to practitioners were also communicated to planners	Helfield et al. 2007, Palm et al. 2007, Gardeström et al. 2013, Polvi et al. 2014, Hasselquist et al. 2015, Nilsson et al. 2015, Vindel River Life 2015

LITERATURE CITED

Ambrose, L. G., and S. D. Wilson. 2003. Emergence of the introduced grass *Agropyron cristatum* and the native grass *Bouteloua gracilis* in a mixed-grass prairie restoration. *Restoration Ecology* 11:110–115.

Aradottir, A. L. 2007. Restoration of birch and willow woodland on eroded areas. Pages 67–74 in G. Halldorsson, E. S. Oddsdottir and O. Eggertsson, editors. *Effects of afforestation on ecosystems, landscape and rural development*. TemaNord 2007:508, Reykholt, Iceland, June 18–22, 2005. http://norden.diva-portal.org/smash/record.jsf?pid=diva2%3A702668&dswid=4935

Arnalds, A. 2005. Approaches to landcare: a century of soil conservation in Iceland. *Land Degradation and Development* 16:113–125.

Bakker, J. D., and S. D. Wilson. 2004. Using ecological restoration to constrain biological invasion. *Journal of Applied Ecology* 41:1059–1065.

Bakker, J. D., S. D. Wilson, J. M. Christian, X. Li, L. G. Ambrose, and J. Waddington. 2003. Contingency of grassland restoration on year, site and competition from introduced grasses. *Ecological Applications* 13:137–153.

Bell, R. M., and J. Kolb. 2013. Various alteration stages in the Nalunaq gold deposit, south Greenland. *Mineral Deposit Research for a High-Tech World* 1–4:1093–1096.

Berglund, B., L. Hallgren, and Á. L. Aradóttir. 2013. Cultivating communication: participatory approaches in land restoration in Iceland. *Ecology and Society* 18(2):35. http://dx.doi.org/10.5751/ES-05516-180235.

Dominy, S. C., E. J. Sides, O. Dahl, and I. M. Platten. 2006. Estimation and exploitation in an underground narrow vein gold operation: Nalunaq Mine, Greenland. *Australasian Institute of Mining and Metallurgy Publication Series* 2006:29–44.

Elmarsdottir, A., A. L. Aradottir, and M. J. Trlica. 2003. Microsite availability and establishment of native species on degraded and reclaimed sites. *Journal of Applied Ecology* 40:815–823.

Feld, C. K., S. Birk, D. C. Bradley, D. Hering, J. Kail, A. Marzin, A. Melcher, D. Nemitz, M. L. Pedersen, F. Pletterbauer, D. Pont, P. F. M. Verdonschot, and N. Friberg. 2011. From natural to degraded rivers and back again: a test of restoration ecology theory and practice. *Advances in Ecological Research* 44:119-209.

Forsvarsbygg. 2015. www.forsvarsbygg.no/Prosjekter/Hjerkinn-PRO/. Accessed 29 June 2015.

Gardeström, J., D. Holmqvist, L. E. Polvi, and C. Nilsson. 2013. Demonstration restoration measures in tributaries of the Vindel river catchment. *Ecology and Society* 18(3):8. http://dx.doi.org/10.5751/ES-05609-180308.

Hagen, D., and M. Evju. 2013. Using short-term monitoring data to achieve goals in a large-scale restoration. *Ecology and Society* 18(3):29. http://dx.doi.org/10.5751/ES-05769-180329.

Hasselquist, E.M., C. Nilsson, J. Hjältén, D. Jørgensen, L. Lind & L. E. Polvi. 2015. Time for recovery of riparian plants in restored northern Swedish streams: a chronosequence study. *Ecological Applications* 25:1373-1389.

Heidinga, L., and S. D. Wilson. 2002. The impact of an invading alien grass (*Agropyron cristatum*) on species turnover in native prairie. *Diversity and Distributions* 8:249–258.

Hekkala, A.-M., M.-L. Päätalo, O. Tarvainen, and A. Tolvanen. 2014a. Restoration of young forests in eastern Finland: benefits for saproxylic beetles (Coleoptera). *Restoration Ecology* 22:151–159.

Hekkala, A.-M., O. Tarvainen, and A. Tolvanen. 2014b. Dynamics of understory vegetation after restoration of natural characteristics in the boreal forests in Finland. *Forest Ecology and Management* 330:55–66.

Hekluskógar. 2015. www.hekluskogar.is. Accessed 29 June 2015.

Helfield, J. M., S. J. Capon, C. Nilsson, R. Jansson, and D. Palm. 2007. Restoration of rivers used for timber floating: effects on riparian plant diversity. *Ecological Applications* 17:840–851.

Hewison, R. L., E. C. Brown, R. V. Birnie, and J. Alexander. 2016. *Continued long-term monitoring of calcareous grasslands and erosion within the Trotternish Ridge SAC*. Scottish Natural Heritage Commissioned Report. Inverness, Scotland, UK, in press.

Hunziker, M., B. D. Sigurdsson, G. Halldorsson, W. Schwanghart, and N. Kuhn. 2014. Biomass allometries and coarse root biomass distribution of mountain birch in southern Iceland. *Icelandic Agricultural Sciences* 27:111-125.

Laine, A. M., M. Leppälä, O. Tarvainen, M.-L. Päätalo, R. Seppänen, and A. Tolvanen. 2011. Restoration of managed pine fens: effect on hydrology and vegetation. *Applied Vegetation Science* 14:340–349.

Life Peatlands Project. 2015. www.lifepeatlandsproject.com/htm/summary/progress.php. Accessed 29 June 2015.

Lunt, P., T. Allot, P. Anderson, M. Buckler, A. Coupar, P. Jones, J. Labadz, and P. Worrall. 2010. Peatland restoration. Scientific Review commissioned by IUCN UK Peatland Programme Commission of Inquiry into Peatland Restoration, Edinburgh, UK. [online] URL: http://www.iucn-uk-peatlandprogramme.org/sites/www.iucn-uk-peatlandprogramme.org/files/Review%20Peatland%20Restoration,%20June%202011%20Final.pdf

MacDougall, A. S., S. D. Wilson, and J. D. Bakker. 2008. Climatic variability alters the outcome of long-term community assembly. *Journal of Ecology* 96:346-354.

Martinsen, O.-E., and D. Hagen. 2010. Tilbakeføring av Hjerkinn skytefelt til sivile formål (Hjerkinn PRO) *[Restoration of Hjerkinn firing range into nature conservation areas (Hjerkinn PRO)]*. Pages 35–37 *in* D. Hagen and A. B. Skrindo, editors. *Restaurering av natur i Norge—et innblikk i fagfeltet,* *fagmiljøet og pågående aktivitet [Restoration of nature in Norway—a glimpse into the thematic field, professional institutions and ongoing activity]*. NINA Temahefte 42, Norwegian Institute for Nature Research, Trondheim, Norway.

Nilsson, C., L. E. Polvi, J. Gardeström, E. M. Hasselquist, L. Lind, and J. M. Sarneel. 2015. Riparian and in-stream restoration of boreal streams and rivers: success or failure? *Ecohydrology* 8:753-764.

Óskarsson, H. 2009a. Hekluskógar: endurheimt birkiskóga í nágrenni Heklu [*Heklaforest: restoration of birch woodlands in the vicinity of the Hekla volcano*]. *Fræðaþing landbúnaðarins* 6:286–290.

Óskarsson, H. 2009b. Hekluskogar: Islands største reetablering af birkeskove. *Skoven* 41(1):35–39.

Óskarsson, H. 2011. Hekluskógar [Heklaforest]. Pages 71–74 in Á. L. Aradóttir and G. Halldórsson, editors. *Vistheimt á Íslandi* [*Ecological restoration in Iceland*]. Agricultural University of Iceland and Soil Conservation Service of Iceland, Reykjavík, Iceland.

Palm, D., E. Brännäs, F. Lepori, K. Nilsson, and S. Stridsman. 2007. The influence of spawning habitat restoration on juvenile brown trout (*Salmo trutta*) density. *Canadian Journal of Fisheries and Aquatic Sciences* 64:509–515.

Pedersen, A. B. 2010. The fight over Danish nature: explaining policy network change and policy change. *Public Administration* 88:346–363.

Pedersen, M. L., J. M. Andersen, K. Nielsen, and M. Linnemann. 2007a. Restoration of Skjern River and its valley: project description and general ecological changes in the project area. *Ecological Engineering* 30:131–144.

Pedersen, M. L., N. Friberg, J. Skriver, A. Baattrup-Pedersen, and S. E. Larsen. 2007b. Restoration of Skjern River and its valley: short-term effects on river habitats, macrophytes and macroinvertebrates. *Ecological Engineering* 30:145–156.

Pedersen, M. L., K. K. Kristensen, and N. Friberg. 2014. Re-meandering of lowland streams: will disobeying the laws of geomorphology have ecological consequences? Plos One 9, e108558.

Petursdottir, T., O. Arnalds, S. Baker, L. Montanarella, and A. L. Aradottir. 2013a. A social-ecological system approach to analyze stakeholders' interactions within a large-scale rangeland restoration program. *Ecology and Society* 18(2):29. http://dx.doi.org/10.5751/ES-05399-180229.

Petursdottir, T., A. L. Aradottir, and K. Benediktsson. 2013b. An evaluation of the short-term progress of restoration combining ecological assessment and public perception. *Restoration Ecology* 21:75–85.

Polvi, L. E., C. Nilsson & E. M. Hasselquist. 2014. Potential and actual geomorphic complexity of restored headwater streams in northern Sweden. *Geomorphology* 210:98–118.

Schmidt, G. 2000. Bændur græða landið: viðhorf bænda [*Farmers heal the land: farmers' perspective*]. *Ráðunautafundur* 2000:93–98.

Similä, M., K. Aapala, and J. Penttinen, editors. 2014. *Ecological restoration of drained peatlands: best practices from Finland*. Metsähallitus Natural Heritage Services and Finnish Environment Institute, Vantaa, Finland.

Similä, M., and K. Junninen, editors. 2012. *Ecological restoration and management in boreal forests: best practices from Finland*. Metsähallitus Natural Heritage Services, Vantaa, Finland. URL: http://julkaisut.metsa.fi/assets/pdf/lp/Muut/ecological-restoration.pdf.

Tarvainen, O., A. M. Laine, M. Peltonen, and A. Tolvanen. 2013. Mineralization and decomposition rates in restored pine fens. *Restoration Ecology* 21:592–599.

Vindel River Life. 2015. www.vindelriverlife.se. Accessed 29 June 2015.

Wilson, S. D. , J. D. Bakker, J. M. Christian, X. Li, L. G. Ambrose, and J. Waddington. 2004. Semiarid old-field restoration: is neighbor control needed? *Ecological Applications* 14:476–484.

Wilson, S. D., and M. Pärtel. 2003. Extirpation or coexistence? Management of a persistent introduced grass in a prairie restoration. *Restoration Ecology* 11:410–416.

Wilson, S. D., and B. D. Pinno. 2013. Environmentally-contingent behaviour of invasive plants as drivers or passengers. *Oikos* 122:129–135.