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1. Summary and conclusions

The present book contains the result of the Nordic network ReNo – Restoration of Damaged Ecosystems in the Nordic Countries, which was launched in 2009 as a theme project of the Nordic Council of Ministers, appointed by the Icelandic Ministry for the Environment. All the Nordic countries and the associated territory of Faroe Islands participated in the network.

Twelve Nordic institutions were directly involved in the ReNo network, representing the scientific community, public and private organisations and NGO's working with ecological restoration. The primary tasks of the network were to assess and evaluate ecological restoration activities in the Nordic countries and consolidate information on ecological restoration in the region. The network held an international conference, Restoring the North, in 2011 on ecological restoration in northern regions.

Over 30 publications were produced by the ReNo network or in conjunction with the network, including reports on the status of restoration in the Nordic countries, guidebooks on restoration, and selected contributions from the Restoring the North conference. Results from the network were also presented at workshops, seminars and short courses held by or in conjunction with the ReNo network, at the SER conference in Mexico 2011 and in various media. In addition, members of the ReNo network collaborated with the Ecological Restoration Task Force IUCN-WCPA on Best Practice Guidelines for Ecological Restoration in Protected Areas.

The ReNo network has reviewed the extensive work on ecological restoration in the Nordic countries and recommends that this important activity should be more firmly anchored in Nordic environmental policy. The following subjects were identified as keys for enhancing ecological restoration in the Nordic countries:

- Secure a strong Nordic commitment to the Aichi targets of restoring 15% of damaged ecosystems by 2020
- Advocate a long-term ecological restoration policy, both on national and Nordic levels, and improve the legal framework for ecological restoration in the Nordic countries
- Enhance Nordic cooperation on ecological restoration, within the Nordic region as well as in the EU and other international contexts
- Make evaluation of ecological restoration projects mandatory, improve methods, and advocate the use of adaptive management practices for improving project implementation and management
- Advocate development of guidelines for ecological restoration in the Nordic countries. Such guidelines are important for securing proper planning, implementation and follow-up of restoration projects
- Invest in human resources, through education and other outreach activities related to ecological restoration, with a primary focus on actors in ecological restoration
- Advocate public participation in ecological restoration and identify ways to increase public participation in restoration

Ecological restoration has the potential to make a critical contribution for the benefit of the global environment, including fighting biodiversity loss; mitigating climate change; increasing resilience to environmental hazards; and improving general human living conditions. The ReNo network has consolidated knowledge on ecological restoration work in the Nordic region and facilitated exchange of this knowledge within and between the Nordic countries. It is the hope of the ReNo network group that this and other accomplishments of the network will benefit ecological restoration and environmental policy in the Nordic countries and strengthen Nordic influence on environmental policy in the EU and other international contexts.

2. Project overview

The aims of the ReNo network were to: (a) enhance knowledge and professional skills in ecosystem restoration in the Nordic countries, (b) increase awareness of the importance and the potential of ecosystem restoration for environmental quality and nature conservation, (c) develop multidisciplinary paradigms for ecosystem restoration in order to increase the effectiveness of restoration projects, (d) identify potential knowledge gaps and, if needed, design new research programmes and (e) provide recommendations for improved policy instruments. These aims were approached through the following steps:

- Creation of a Nordic forum for ecological restoration
- Assessment and evaluation of ecological restoration activities in the Nordic countries
- Consolidation of experiences from restoration of damaged ecosystems in northern regions
- Dissemination of results from the network where knowledge gaps and inadequate policy instruments are identified and current paradigms and guidelines for ecological restoration in the Nordic countries are reviewed

2.1 Nordic forum on ecological restoration

The creation of a Nordic forum on ecological restoration was considered to be an important step for enhancing restoration in the Nordic countries; no such forum has previously existed. This has enhanced the flow of information about valuable experiences and findings between and within countries. Information gathered by the ReNo network showed that different countries specialize to some extent in different types of restoration activities (Hagen et al. in review). This has contributed to the establishment of several centres of excellence in ecolog-

ical restoration in the region. Facilitation of information exchange between these centres within the Nordic region may be expected to benefit restoration work in the region and strengthen the Nordic influence in ecological restoration and environmental policy in the EU and other international contexts.

Twelve Nordic institutions were directly involved in the ReNo network. In addition several institutions participated in national networks, which have gathered information on ecological restoration in different countries. The participating institutions represented the scientific community, public organisations working with ecological restoration, public organisations working with protection of the environment, energy companies, road administrations and NGOs. The ReNo network consisted of 2–4 individuals from each country representing: (1) science, (2) policy and administration and (3) practitioners. A list of participating institutions and network participants is given in Appendix 1.

2.2 Assessment of ecological restoration activities

The primary task of the ReNo network was to assess and evaluate ecological restoration activities in the Nordic countries. Within the partaking countries, national networks were established for gathering information on restoration projects and research on ecological restoration. These networks have conducted several workshops attended by governmental and scientific institutions, energy companies, public road administration and NGO's. Three of the countries, Norway, Iceland and the Faroe Islands, have compiled and published national assessments of restoration activities in their countries (Hagen & Skrindo 2010a, Aradóttir and Halldórsson 2011, Fosaa & Simonsen 2011), while in Denmark, Finland and Sweden information about most restoration projects has already been published as part of final reports to the EU-LIFE Nature programme and other funding agencies as well as in other publications (Nilsson 2007, Degerman 2008). Therefore, analysis of these projects was deemed to be of additional value for the network. Analyses of EU-LIFE Nature ecological restoration projects have been conducted in Denmark (Morsing et al. submitted) and Sweden (Johansson 2011) and Finland has produced guidebooks of forest restoration (Similä and Junninen 2011, Similä

and Junninen 2012), and peatland restoration (Aapala 2012) in conjunction with the ReNo network.

2.3 Dissemination

Over 30 publications have been produced either by the ReNo network or in conjunction with it. A list of these publications is in Appendix 2. This includes the above-mentioned reports on the status of restoration in the Nordic countries; guidebooks of restoration; MS theses; book of abstracts from the conference Restoring the North; and a special feature of the journal *Ecology & Society* with selected contributions from the conference is underway and the first papers will be published in 2012. The reports on the status of restoration in the Nordic countries contain descriptions of more than 100 individual ecological restoration projects, including restoration of specific animal populations, restoration of freshwater ecosystems, wetlands, heathlands, forest ecosystems, etc. This information, together with other information gathered by the network, was used to analyse ecological restoration work across the Nordic countries (Hagen et al. in review). Furthermore, drivers in ecological restoration projects were analysed, using Iceland as a case study (Aradóttir et al. to be submitted).

Members of the ReNo network arranged and contributed to various activities, disseminating results from the network. These included:

- Collaboration with Ecological Restoration Task Force IUCN-WCPA on Best Practice Guidelines for Ecological Restoration in Protected Areas. This work was confirmed as a key deliverable under the CBD's Programme of Work on Protected Areas at the 2010 Nagoya, Japan Conference of Parties. The IUCN has committed to publish guidelines in 2012
- A workshop on the status of ecological restoration in the Nordic countries, held at Hotel Glymur in West Iceland, August 17–19, 2010
- A seminar on restoration ecology held at NINA on the 23rd of September 2010. The aim of the seminar was to establish a network and contacts between scientists and students working with restoration ecology in alpine/arctic environments

- A poster presentation of the ReNo network at the 4th SER International World Conference on Ecological Restoration held in Mérida, Yucatán, México, August 21–25, 2011
- The PhD course “Perspectives on Ecological Restoration” which was held during 27–28 January and 17–18 February 2011 at the Department of Ecology and Environmental Science, Umeå University
- A restoration ecology course at the University of Oulu, March–May 2011
- Survey of peatland restoration sites in Finland conducted during the summer of 2011
- Initiation of a multidisciplinary peatland strategy project of Northern Ostrobothnia in Finland in 2011
- International conference: *Restoring the North*, on restoration of damaged ecosystems in northern regions, held in Selfoss, Iceland, 20–22 October, 2011
- A poster presentation of results from the ReNo network at the 8th European Conference on Ecological Restoration, September 9–14, 2012, České Budějovice, Czech Republic
- Presentations at national conferences and other forums within participating countries

Other media were also used to disseminate results from the network and enhance general interest in ecological restoration, including the home page of the network (<http://www.reno.is>), home pages of participating institutes, interviews in newspapers and radio and presentations at various forums.

3. Ecological restoration in the Nordic countries

Extensive human induced ecosystem degradation, primarily over the past 50 years, has resulted in degradation of important ecosystem services and a substantial loss in the diversity of life on Earth (MEA 2005). This has serious sociological and economic consequences, including augmentation of global climate change and a negative impact on food security and important ecosystem services, such as hydrology, fertility, and resilience against natural disasters (MEA 2005). Global conservation efforts have not managed to stop this development and biodiversity continues to decline at an accelerating rate (Butchart et al. 2010).

Figure 1



Ecosystem degradation severely reduces ecosystem resilience to natural hazards. Here, degraded areas in South Iceland covered with volcanic ash from the eruption in Eyjafjallajökull in 2010.

Photo: Hreinn Óskarsson.

Ecosystem degradation is a pronounced problem in all the Nordic countries, but varies in nature, severity and scale between the countries and geo-regions. In many cases native ecosystems have been overexploited, disturbed and even destroyed, disrupting the cycles of energy, nutrients and water, and damaging biodiversity and ecosystem services. This includes decimation of natural forest ecosystems, drainage of wetlands, channelization of streams and rivers for timber floating, fragmentation of alpine areas and damage to heathland ecosystems by heavy grazing (Eggertsson et al. 2008, <http://dnweb12.dirnat.no/inon/>, Halldórsson et al. 2011, Hagen et al. in review). Efforts to reverse this development have often involved use of exotic species, which has further reduced the natural habitats of many species of flora and fauna (Elmarsdottir & Magnusson 2007, Fjellberg et al. 2007, Elmarsdottir et al. 2008).

Forestry and agriculture have for a long time, exerted the major land-use pressure on ecosystems in the Nordic region. The natural forests of Fennoscandia have been influenced by human impact during the last 5,000 years, primarily by cutting for timber, fuel and other wood products, grazing, and forest clearing for agricultural purposes such as creation of fields and pastures for grazing. This led to large scale clearing of natural forests, primarily in Denmark, South Sweden and West Norway (Eggertsson et al. 2008).

Figure 2



Example of a concrete wall in the Vindel River, built to concentrate river flow and floating timber into a single channel. Walls like this have left large areas of river channels dry and reduced riparian primary production as well as fish migration and spawning. Photo: Christer Nilsson.

Following and concurrent to forest clearance, ecosystem degradation and soil erosion started. In Denmark the first signs of soil erosion date back to 500 BC (Rasmussen & Bradshaw 2005). Similar processes occurred following human settlement in the Faroe Islands and Iceland, which initiated a dramatic ecosystem degradation and soil erosion, especially in Iceland (Johansen 1989, Arnalds et al. 2001, Simpson et al. 2001, Crofts 2011).

In order to counteract present and past ecological degradation, all the Nordic countries emphasize ecological restoration to some degree (Hagen et al. in review). Ecological restoration is also recognised to be of high significance in combating degradation of ecosystems and biological diversity on a global scale (MEA 2005, CBD 2011). The aim of ecological restoration is to initiate and accelerate natural processes and restore functions and services of damaged ecosystems (SER 2004). This concerns biophysical systems, as well as inter-linkages between ecosystems and human societies (Mansourian et al. 2005, Falk et al. 2006, Raven 2007, Petursdottir & Aradottir 2008).

In this context it is important to realise that changes in land use, including increased urbanization, call for new approaches and solutions for restoring

and conserving natural capital for human welfare, water protection, and other ecosystem services. Research shows the importance of public access to natural systems for human welfare and health (Sveinsdottir et al. 2008). Ecological restoration needs to be considered in context, with public access and human welfare included together with a range of ecosystem services.

The scale of restoration activities and prioritization of such activities is quite different between the Nordic countries. Restoration activities in the region are summarized in Hagen et al. (in review) and divided into five major classes by habitat, i.e., restoration of natural forests, wetlands/peatlands, freshwater systems, heathlands/natural grasslands and cultural landscapes.

Figure 3



Reopened piped river in Oslo. Urban projects often take place in small areas and in close relation to other types of land use and a number of stakeholder groups. Photo: Dagmar Hagen.

Restoration in Denmark concerns mostly conversion to a more “nature friendly” management practice rather than strict ecological restoration (Larsen & Raulund-Rasmussen, in manuscript). Restoration activities are mainly related to abandoned agricultural land and restoration of wetlands (Hagen et al. in review). The currently largest restoration project is the restoration of the Skjern River (Pedersen et al. 2007). Restoration is mostly on public land, with costs paid by the state, EU funds and private funds.

Ecological restoration in the Faroe Islands is on a small scale and is restricted to some minor wetland projects. However, in connection with land use projects such as hydropower exploitation, environmental impact assessment is required, and these assessments provide information on areas that can be useful in future restoration projects. The current largest restoration project is the restoration of the wetland Holmin a Eidi (Fosaa & Simonsen 2011). Restoration costs are mostly paid by public institutions.

In Finland the highest priorities are on restoration of natural forests and peatlands. More than 150 km² of forests and 180 km² of peatlands have been restored so far (Virnes 2011). The largest restoration project is currently Boreal Peatland Life, which aims at restoring nearly 43 km² of various kinds of peatlands. Most activities are on state owned land. The costs are paid by a mixture of national and EU funds (Hagen et al. in review).

Revegetation of eroded land is prioritized in Iceland, along with restoration of natural woodlands and wetlands. More than 1,500 km² of heathland/grassland and 200 km² of native birch woodlands have been restored so far. The largest ecological restoration project is currently the Heklungar project, which aims at restoring native woodland on ca. 900 km² of eroded land near the volcano Mt Hekla. Costs are mostly paid by the state, but energy companies, road authorities and landowners are responsible for an increasing number of projects (Halldórsson et al. 2011).

Figure 4



Storm simulation in a Finnish forest by pulling down trees with a caterpillar to increase coarse woody debris and open microhabitats for seedling germination. Photo: Anne Tolvanen.

In Norway the highest priority is on restoration of the cultural landscape, freshwater systems and heathland/natural grassland, but the Norwegian Directorate for Nature Management recently presented a national plan for restoration of wetlands. The currently largest ecological restoration project in Norway is HjerkinPRO, the restoration of a former military training area (165 km²) in the alpine zone. Costs are mostly paid by the state (Hagen et al. in review).

In Sweden the highest priority is on restoration of freshwater systems and wetlands. The currently largest restoration project is GRACE – Grazing and restoration of archipelago and coastal environments. Costs are covered by a mixture of EU, national and private funding (<http://www.lansstyrelsen.se>).

In general, forestry and agriculture are regarded as the most important land-use pressures on ecosystems in the Nordic region. Other major land-use pressures are: human induced grazing, tourism/outdoor activities, construction of infrastructure/urbanization, pollution and use of non-native species. However, land-use pressures are different among the countries. Overgrazing is considered to be the most important factor in Iceland

and the Faroe Islands; forestry in Finland and Sweden; forestry, agriculture and non-native species in Denmark, and in Norway forestry, lack of human induced grazing pressure on cultural habitats and construction of infrastructure/urbanisation (Hagen et al. in review).

Figure 5



Restoration in lichen woodland, Norway. Organic mats used for erosion control and to support early establishment following severe disturbance. The site is used for military training with heavy vehicles. Photo: Dagmar Hagen.

4. Synthesis from the conference Restoring the North

There is a common need in all the Nordic countries for building and utilizing knowledge in restoration ecology to face current land-use challenges and threats to biodiversity. An essential part of this work was to assemble a review of ecological restoration in this region (Hagen et al. 2011). For that purpose the ReNo network held an international conference on restoration of damaged ecosystems in northern regions at Selfoss, Iceland, 20–22 October 2011. A total of 79 participants from eight countries attended the conference; scientists, students and representatives from institutions responsible for ecosystem restoration and nature protections. At the conference, 25 oral and 25 poster contributions were presented in the following six sessions:

- Restoration in the north – challenges and opportunities
- Setting objectives and evaluating success in restoration
- Legislation, policy and implementation of restoration
- The role of theory in restoring ecosystem structure and function
- Poster session, addressing the same issues as the oral sessions
- Achievements and future of ReNo

The first session was opened by a historical overview of restoration research in arctic and sub-arctic regions from the 1960s to the present (Forbes 2011). In general, restoration in the area is faced with increasing human impacts; lack of controlled long-term studies; diminishing sources of local/regional plant material; invasive plants and climate change. However, climate change may facilitate ecosystem restoration, and advanced mitigation efforts and more stringent environmental regulations in the

Russian Arctic give hope for new opportunities in ecological restoration in the region. The opening presentation was followed by presentations showing the range of challenges and opportunities in restoration in the Nordic regions.

Peatlands in Finland have been extensively drained and forests are affected by silvicultural practices. To counteract this, more than 150 km² of forests and 180 km² of drained peatlands have been restored (Virnes 2011). Planning, implementation and monitoring of such restoration activities is conducted through a specific framework which secures constant feedback between the different stages and continuous improvement of the restoration methods (Virnes 2011). Monitoring of peatland restoration is carried out on all restored sites to detect the need for corrective actions and to solve possible problems as early as possible (Similä et al. 2011a). Monitoring of forest restoration is conducted through a network which includes 24 nature conservation areas with a total of 150 permanent plots (Similä et al. 2011b).

Wetlands in Iceland have also been extensively drained and wetland protection and restoration is one of the policy priorities of the Icelandic Ministry for the Environment. In spite of this, wetland restoration in the country is at an early stage. Some small lakes have been restored including Kolviðarnesvatn in West Iceland, where the success of the restoration has been studied (Magnúsdóttir et al. 2011). Part of the wetlands to the east of the river Ölfusá in South Iceland have been restored, the area is one of Iceland's most important wetland areas for birdlife and hosts several rare plant species (Sigurðardóttir 2011).

Figure 6



Restored wetland in Mývatnssveit, North Iceland. Photo: Ása L. Aradóttir.

Drainage of wetlands has caused a significant increase in Iceland's GHG emission. That could be counteracted by restoration of wetlands and therefore it is important to develop methods for verifying the success of restoration in reducing GHG emission from drained wetlands (Óskarsson & Ólafsdóttir 2011). Restoration of wetlands is the only significant restoration activity conducted in the Faroe Islands (Hansen & Fosaa 2011).

Ecological restoration of stream water is important in the Nordic countries. Rivers and small streams have been dammed, channelized for floating timber, harnessed for hydropower production and disturbed by other activities. This can affect the resilience of riparian ecosystems to a changing environment. Global warming can be expected to affect freezing and thawing processes in streams in cold regions, which may be harmful for species diversity in the riparian zone. In North Sweden the relationship between channel topography and destructive ice formation has been studied and recommendations prepared for proactive restoration methods to sustain the biodiversity that is typical for boreal streams (Lind & Nilsson 2011). The possibility of using restoration to increase the resilience of riparian zones to climate change has also been studied (Kuglerová & Jansson 2011).

Figure 7



Skjern River in Jutland, Denmark, after restoration. Restoration of the river is hitherto the largest ecological restoration project in Denmark. Photo: Karsten Raulund-Rasmussen.

Furthermore, a Swedish study showed that riparian vegetation generally benefitted from dam removal whereas benthic invertebrates seemed to be negatively affected (Renöfält 2011). An Icelandic study showed that salmon populations can be restored by securing minimum flow in a dammed river system and stocking the river with salmon juveniles (Antonson & Árnason 2011).

Native forests and woodlands throughout the Nordic region have been heavily affected by human activities. Icelandic birch woodlands have been decimated through the history of human settlement that has seriously reduced the resilience of Icelandic ecosystems to natural disasters, such as fallout of volcanic ash. A large scale restoration project of native birch woodlands Hekluskogar has been initiated with the aim of restoring 900 km² of woodlands on eroded areas in the vicinity of the volcano Mt Hekla (Óskarsson et al. 2011). Degradation of soil biota has been shown to have a negative effect on the survival of tree seedlings and is one of the obstacles to restoration of woodland on eroded land (Oddsdóttir et al. 2011). An increase in volcanism in Iceland calls for strategic efforts to restore ecosystems in the active volcanic zone of the country (Ágústsdóttir et al. 2011a). Restoration projects that affect the inhabitants in large areas benefit from

participatory approaches which include landowners and other stakeholders in the process of planning and implementation (Berglund et al. 2011).

Several studies on restoration of heathland and alpine environment were presented at the conference. In Norway a study on short term vegetation recovery after transplantation in an alpine environment showed that grasses were more tolerant to transplantation than woody plants (Rosef & Pedersen 2011). Similarly, an Icelandic study on turf transplantation showed that dwarf shrubs are more susceptible to the size of transplanted turfs than grasses (Aradóttir 2011).

Figure 8



Transplanted turf used to restore natural vegetation after construction work in Hellisheiði, Iceland. Photo: Ása L. Aradóttir.

Figure 9



Willow communities on sand dunes south of Mt Hekla, Iceland. The area was revegetated with Lyme grass, which is still visible, but now willows have colonized the dunes. Photo: Ása L. Aradóttir.

Treatment with commercial grass seed is a common method in revegetation. This may impede the establishment of local vegetation, however, as shown by a study in Norway where revegetation with commercial grass seed mixtures did not lead to a vegetation cover of native species after 21 years (Hansen 2011). Another Norwegian study showed that seven years after revegetation, plant cover was highest in the most intensive treatment, which included seeding with *Festuca rubra* whereas species richness was highest in the least intensive treatment, (Hagen & Evju 2011). In Norwegian mountain areas plant cover was found to develop faster in plots seeded with a mixture of imported seeds than plots seeded with a mixture composed of Norwegian ecotypes, but the latter had higher diversity of species (Aamlid et al. 2011).

Using seed-containing hay transfer was shown to be feasible to restore native vegetation on a degraded area in Iceland, but success depended on time of transfer (Grétarsdóttir 2011). Another study showed that the build-up of soil organic matter in areas revegetated by *Leymus arenarius* — a species widely used to stabilize sandy areas in Iceland — differed from that of other revegetation methods due to the constant burial of organic matter in the *Leymus* dunes by incoming sand (Stefánsdóttir 2011).

Figure 10-11



The removing of roads and restoration of a military training area in Dovrefjell, Norway. Above, before removal of the road. Below, after removal of the road. Photos: Dagmar Hagen.

Alpine and subarctic environments are highly vulnerable to disturbances and often difficult to restore. Moss heaths dominated by *Racomitrium lanuginosum* are prominent in alpine areas in Iceland, but methods for their restoration have been lacking. Recent greenhouse and field experiments indicate that distribution of moss fragments of *R. lanuginosum* can be used to accelerate colonization of the species on disturbed areas (Magnúsdóttir & Aradóttir 2011). The process of restoring an alpine environment may take several decades as shown by studies on the restoration of alpine spoil heaps in Norway, where the use of local plant material or promotion of natural regeneration is recommended (Rydgren et al. 2011). The Norwegian Defense Estates Agency manages large areas of rich and varied biodiversity, where maintenance of functional training areas is needed, while at the same time ensuring that important areas for biodiversity are preserved. Therefore, a manual for ecological restoration has been developed which provides guidelines for identification of preventive and remedial measures in order to minimize negative effects and offers descriptions of procedures and costs related to implementing appropriate measures (Drageset & Selvaag 2011).

Figure 12-13



bórsmörk, South Iceland. Above, spreading of birch seed for restoring the native woodland. To the right, birch seedlings in an area under restoration. Photos: Ása L. Aradóttir.

The need for setting objectives and evaluating restoration was the focal point of the second session of the conference. Experience suggests that restorationists need to (a) set clear objectives; (b) use multiple indicators and specific standards to assess outcomes; (c) introduce assemblages of species that use resources differentially and test for complementarities; (d) seek and employ “superplants” that perform multiple ecosystem services at high levels; and (e) conduct restoration within an adaptive restoration framework (Zedler 2011). A case study on driving forces behind EU-LIFE nature ecological restoration projects in Denmark showed three categories of project objectives: conservation of specific species, maintenance of certain desired nature types in natural areas, and abandoning farming or traditional farming in former reclaimed sites (Thomassen et al. 2011). All the reviewed projects focused on the improvement of living conditions for certain species (Thomassen et al. 2011).

In Iceland several factors have been found to be major drivers of restoration (Aradóttir et al. 2011). The primary driver during most of the twentieth century was the need of reclaiming barren land to use for grazing or hay production. New and more complex drivers have emerged in recent decades, including carbon sequestration, restoration as a mitigation of vegetated land damaged by construction work and restoration of biodiversity (Aradóttir et al. 2011). A case study using a chronosequence of stream restoration sites to assess the development of ecosystem processes in northern Sweden was presented as a part of a project examining the links between the success of ecological restoration and societal actors’ interests and institutional structures (Hasselquist et al. 2011).

The third session was opened by a presentation on legislation, policy and implementation of restoration (Baker 2011). The fact that the value of ecological restoration rests not just on ecological performance, but must also be considered in historical, social, cultural, political, aesthetic and moral contexts, is often overlooked. Therefore, it is important to identify the role of social science in ecological restoration and secure mutual exchange between the natural and social sciences in this field (Baker 2011).

A proposal for a National Strategy for Mires and Peatlands has been submitted to the Finnish Minister of Agriculture and Forestry. However, sustainable strategies are compromises, which may imply the risk of scientific information being overrun by local politics and employment needs

(Tolvanen 2011). In Iceland, a study has been initiated with the aim of designing instruments for evaluating the impacts of agri-environmental policies on rangeland restoration amongst sheep farmers and the sustainability of the related social-ecological system (Pétursdóttir 2011). In those Nordic countries, belonging to the EU, funding from EU is among the major drivers of restoration. If Iceland becomes an EU member this could also apply there, primarily in relation to improvements in legislation and sustainable land use policy. EU solutions, however, may not always be relevant due to Iceland's uniqueness with respect to nature, extensive land degradation and land use (Ágústsdóttir et al. 2011).

In Sweden the Vindel River LIFE project initiated in 2010 aims at restoring a major river system that was altered to facilitate timber floating (Gardeström et al. 2011). The restoration work was preceded by a legal consultation procedure with major stakeholders and local inhabitants in the region. The ecological success of the restoration actions will be evaluated by monitoring the riparian and stream habitats (Gardeström et al. 2011). In Denmark, the national forest programme specifies so-called "close to nature silviculture" as a guiding principal for managing the public forests, which aims at mimicking natural disturbance regimes and increasing the use of indigenous species (Larsen & Raulund-Rasmussen 2011). Natural regeneration and selection supported by group or target diameter cuttings is also favoured (Larsen & Raulund-Rasmussen 2011).

Figure 14



Stretch of a tributary to the Vindel River in northern Sweden, restored by addition of large boulders and trees. To make this stream available for timber floating, all of its former large structures were removed or destroyed. Photo: Christer Nilsson.

Ecological theory has an important, but sometimes underestimated, role in the restoration of ecosystem structure and function. Peatland restoration is based on the theory that ecological processes in peatlands are largely based on the water level. Studies in Finland have shown that 30 years drainage of relatively mature pine fens had little impact on the understorey vegetation, whereas young fens have a capacity to quickly react to a changing environment (Laine & Tolvanen 2011). Traditionally, practical ecological restoration is based on knowledge about existing and past environments rather than possibly very different future conditions, e.g., due to climate change (Nilsson 2011). To counteract this, it is important to choose among well thought out methods and to carry out long-term follow-up studies to increase the potential for making adjustments if a restored site develops in an unwanted or unexpected direction (Nilsson 2011). A large scale experiment on restoration of eroded land in South Iceland demonstrates that the initial inputs in restoration can determine subsequent successional trajectories and simple revegetation treatments can trigger natural succession and development of ecosystem services (Svavarsdóttir et al. 2011).

Invasive species are considered a major threat to Nordic natural environments. The Nootka lupine *Lupinus nootkaensis* and Cow parsley *Anthriscus sylvestris* are considered invasive in Iceland and likely to increase in spread in the future. A committee, initiated in 2009 by the Ministry for the Environment, developed a policy plan with the main focus of keeping the two species from the highlands, nature preserves and other protected sites (Elmarsdóttir et al. 2011b). Attempts have been made to control Cow parsley in a few communities in Iceland, mainly by cutting and herbicide application, but the success of these methods has not been measured (Elmarsdóttir et al. 2011a). The Nootka lupine has been extensively distributed in Iceland. Studies have shown that spraying the lupine with herbicides can effectively eradicate it and reduce its seed bank without severely affecting other vegetation (Jóhannsson et al. 2011). The effect of lupine on the development of native plant communities can vary depending on the conditions and lupine density (Gísladóttir et al. 2011). Long-term experiments have shown that the establishment of native birch plants was inhibited in dense lupine stands but facilitated in more open stands compared to eroded land (Gísladóttir et al. 2011).

Figure 15



Nootka lupine invading heathland in northern Iceland. Photo: Borgþór Magnússon.

Human activities can endanger threatened species and populations, which often are the focal point of restoration. The Icelandic Sea Eagle population was protected by law in 1914 and has been growing since the 1970s, although the population is still threatened, primarily by shooting and disturbance at nesting sites (Skarphéðinsson 2011). Development of methods for preservation of threatened species and plant communities after road construction in Gudbrandsdalen, Norway, was presented at the conference (Enzenberger & Daugstad 2011). In cases where total eradication of a species from its natural habitat happens, reintroduction has been tried. However, in the media this is often presented in the context of nostalgic news, as was the case with the reintroduction of the European beaver to Scotland (Jørgensen 2011).

The growth of ecological restoration depends, among other things, on well-educated professionals in this field. A growing number of universities in the Nordic countries are providing courses and programmes in ecological restoration. One programme, the United Nations University – Land Restoration Training Programme, which started in Iceland in 2010, was presented at the conference (Ægisdóttir & Orradóttir 2011, Orradóttir & Ægisdóttir 2011). The mission of UNU-LRT is to train professionals from developing countries to combat land degradation and restore degraded land and promote sustainable land management in developing countries. The programme is built on the knowledge and expertise gained within Iceland through 100 years of experience in fighting land degradation.

The conference showed that ecological restoration in the Nordic countries covers a wide field of practical restoration and restoration research. The conference also showed that although much has been achieved in ecological restoration in the Nordic countries, there are still many threats to ecosystems in the region which need to be addressed. Furthermore, evaluation of restoration projects in the region was deemed to be incomplete. This was seen as a major obstacle to adaptive management and improvement of restoration methods in the north.

5. Best practice guidance

Hilderbrand et al. (2005) warned of an overly simplified view of restoration which does not recognize and accept the complexity of natural systems and restoration processes. Ecological restoration has been claimed to be flawed by such simplifications (Zedler & Callaway 1999, Hilderbrand et al. 2005). More elaborate planning, implementation and follow-up work is needed for restoration projects to accommodate this natural complexity and the interweaving of the multiple factors involved. Furthermore, ecological restoration interventions should be supported with active communication and outreach programmes (Clewell & Aronson 2007, Hesselink et al. 2007) focused on the initial causes and pressures leading to the degradation, the effects of degradation, and the benefits of restoration (Nellemann & Corcoran, 2010). This approach should target local communities and stakeholders, visitors and employees (Nationalparkverwaltung Bayerischer Wald 2010) and involve developing strategies for appropriate stakeholder engagement (Hesselink et al. 2007).

To improve the results of ecological restoration, Hilderbrand et al. (2005) propose that “restorations should not be one-time events, but are likely to require periodic attention and adaptive management to increase the chances of responsive, adaptive, and successful projects.” Proper restoration guidelines are needed to accomplish this. Textbooks in ecological restoration often contain some guidelines that are useful in planning and implementing restoration projects (see e.g. Whisenant 1999, Bainbridge 2007, Clewell & Aronson 2007, Raven et al. 2007, Howell 2011). More elaborate guidelines for developing and managing ecological restoration projects have been published by the Society for Ecological Restoration International (SER)(Clewell et al. 2005) and members of the ReNo group have contributed to further development of these guidelines. The SER guidelines have, in turn, been the basis for elaboration of guidelines for restoration of specific habitats or regions. In Canada, extensive guidelines, based on the SER guidelines, have recently been published for ecological restoration in

Canada's protected natural areas (Parks Canada & the Canadian Parks Council 2008). For restoration of rivers and streams guidelines published by the European Centre for River Restoration are available (ECRR).

Several guidelines for ecological restoration have been published in the Nordic countries. In Finland, where the major restoration activity concerns restoration of forests and peatland, guidebooks for forest restoration have been published (Similä & Junninen 2011, 2012) and a guidebook for peatland restoration is presently in press (Aapala 2012). In Finland, Sweden and Denmark, many ecological restoration projects are conducted under the EU-LIFE Nature programme. These projects use to some extent guidelines published by the EU, but there are also many national collections of guidelines (e.g. Nilsson, 2007, Degerman 2008). The Norwegian Defense Estates Agency has published a manual for ecological restoration on land managed by the institute (Hagen & Skringo 2010b). In Iceland, a manual for restoration of mines (Umhverfissráðuneytið 2002) is now under review and the Soil Conservation Service has produced several booklets and online instructions on specific restoration issues (see e.g. <http://www.land.is>).

In spite of considerable efforts to produce guidelines of ecological restoration in the Nordic countries in some cases elaborate guidelines for ecological restoration do not exist, as is the case for ecological restoration of major habitats in Iceland, such as heathland/natural grassland, birch woodland and wetland. The shortage of solid guidelines partly mirrors the fact that in many cases it is difficult to define proper targets for restoration. Landscapes are changing, especially at present in the face of climate change, implying that it becomes a great challenge to create ecosystems that are able to function today as well as being able to adapt to future conditions (Nilsson et al. submitted).

However, it is important to realize that a guideline alone can never give the answer to all the detailed steps required in a restoration process. Restoration ecology is far too complex for a simple cookery book approach. In the Nordic countries, there is still need for elaboration of guidelines for several ecosystems, but this should be accompanied by courses and workshops which highlight both successful and less successful restoration projects. The ReNo network has arranged and participated in various educational activities, but we do see the need to increase this effort in

all the countries involved, both inside and outside the university systems but also targeting public authorities who often initiate and fund restoration, the consultant firms that often plan the restoration tasks and the contractors that often see to the practical aspects of carrying out the job.

6. Perspectives in ecological restoration in the Nordic countries

Ecological restoration is a relatively young field of science, whereas the history of reclamation or rehabilitation of degraded areas in the Nordic countries can, in some instances, be traced back more than one hundred years (Aradóttir & Halldórsson 2011). Such activities, which predate the concept “*ecological restoration*”, were obviously not planned to serve the purpose of ecological restoration and mostly had a minor focus on ecological processes. Examples of such projects include seeding/fertilization of degraded heathland; planting/seeding of native forest tree species; seeding spoil heaps, mines and roadsides; and restocking fish populations in regulated rivers (Aradóttir & Halldórsson 2011). These older activities were often related to relatively narrow targets, such as improving pasture land for agriculture; production of firewood; rehabilitation of areas after construction work; and recreational fishing. However, many of these projects have later turned out to fulfill many of the criteria for ecological restoration, although this was not the original purpose (Aradóttir & Halldórsson 2011).

Ecological restoration in the region is still to some extent marked by this history, but concurrent with the development of the concept “*ecological restoration*” there has been a growing understanding and support for a different and broader approach to restoration in the Nordic countries. The focus has thus changed from narrow restoration targets to new and often multifunctional targets. This includes emphasis on: restoration to enhance native biodiversity and environmental quality; restoration in urban areas for the benefit of outdoor activities and public health; restoration to mitigate increased GHG concentrations in the atmosphere; and restoration to increase ecosystem resilience to environmental hazards. More attention is also being given to the social and economic relations/benefits of restoration. Simultaneously, new

actors have been emerging in Nordic restoration. Hitherto, public institutions have been the major players in Nordic ecological restoration (Hagen et al. in review), but recently there has been a growing awareness and interest among different stakeholders, such as private companies and NGOs, to carry out ecological restoration in a large range of habitats (Hagen & Skringo 2010a, Aradóttir & Halldórsson 2011). In general there is also increasing activity in research, development projects, and education and other outreach activities (Hagen & Skringo 2010a, Aradóttir & Halldórsson 2011). This development is positive and must be encouraged in the future.

However, different environmental conditions, different land use history and different needs in different countries must be expected to affect ecological restoration work in the Nordic countries in the future, as in the past (Hagen et al. in review). Regions with favourable natural conditions are often densely populated and marked by ages of intensive agriculture, such as Denmark and South Sweden (Hagen et al. in review). Possibilities for ecological restoration, in the strict sense, are limited in such areas due to high land use pressure (Hagen et al. in review). However, rehabilitation and ecological engineering of degraded areas to improve environmental quality can be highly relevant and beneficial. Regions with less favourable natural conditions, on the other hand, are often marked by livestock grazing, leading to serious land degradation and erosion. In such areas possibilities for restoration are limited by harsh environmental conditions and high costs. Other factors leading to differences between countries in respect to ecological restoration are many, as stated earlier. The future perspectives for ecological restoration in different countries must reflect the existence of multiple factors to a significant extent.

In the future the multiple beneficial effects of ecological restoration must be expected to become of increasing importance in common Nordic policy. This relates primarily to the environment, but also to sociological and economic aspects. Ecological restoration already makes a significant contribution to many of the environmental goals stated in the Nordic Environmental Action Plan 2009–2012 (Nordic Council of Ministers 2008). This contribution must be expected to increase in the future. This would be in harmony with increased international emphasis on ecological restoration.

7. Enhancing ecological restoration

The ReNo network has shown that extensive work is being carried out on ecological restoration and related activities in the Nordic countries. The Nordic countries offer many different challenges and opportunities in relation to ecological restoration, and recognizing and handling these are important for initiating, improving and implementing ecological restoration in the region. The ReNo network group has identified the following subjects as keys for enhancing ecological restoration in the Nordic countries.

- *Evaluation.* One of the results from the ReNo network is that the ecological and social outcomes of restoration projects in the region are, in many cases, not subjected to standardised evaluations. In some cases, project outcomes are not evaluated at all. Monitoring and evaluation are integral parts of adaptive management practices, important for improving project implementation and management. Outcomes of such project evaluation should also be included in the reports from institutions/organisations that do ecological restoration. A significant fraction of restoration work is contracted to entrepreneurs and standardised evaluation of ecological outcomes could reduce the risk of project failure and of discrimination between contractors. In order to remedy this, the ReNo group recommends the development of standardised user-friendly and cost-effective evaluation frameworks in ecological restoration projects
- *Guidelines for restoration.* In the Nordic countries there have been significant efforts to elaborate and publish guidelines of ecological restoration. This work needs to be continued and encouraged. Although it must be kept in mind that ecological restoration is site and context specific and therefore general cookery book designs are generally inappropriate, a lack of guidelines may in some cases hamper

ecological restoration in the region. Such guidelines should address both the biophysical design of locally-based restoration works and stakeholder involvement in order to secure proper planning, implementation and follow-up of restoration projects

- *Human resources.* Education and outreach activities related to ecological restoration in the Nordic countries are increasing. These involve education at the university level, training programmes and practical guidance. Continued growth of these activities is needed in order to provide a strong conceptual framework for the envisioned increase in restoration activities
- *Public participation.* Ecological restoration in the Nordic countries is predominantly initiated and funded by public authorities. However, it is generally accepted that such projects benefit from active public participation. Therefore, increased public participation must be seen as one of the keys to enhancing ecological restoration in the Nordic countries. There is a need to identify ways to increase public participation in restoration, for instance through studies of public participation and influence in restoration projects
- *Legislation and policy.* Growing international emphasis on ecological restoration has started to influence law and policy within individual countries and groups of countries, such as the EU. In some cases, however, current legislation may work against restoration opportunities. Thus, there is a need to improve the legal framework of member countries on ecological restoration. Furthermore, a long term ecological restoration policy should be advocated, both on national and Nordic levels. Such a policy should determine specific steps in restoration of key ecosystems, such as wetlands and forests. Such a policy should be firmly anchored in the Nordic Environmental Action Plan and linked to international environmental conventions
- *Nordic cooperation.* The experience from the ReNo network has shown that Nordic cooperation enhances the flow of information on ecological restoration within the region, within individual countries and between different stakeholder groups. This is highly beneficial for ecological restoration activities in the region and for human resources in this field. Therefore, it is important that this work continues in relation to increasing national and global importance of ecological restoration

- *International activities.* The platform created by the ReNo network should be used to strengthen the Nordic influence in ecological restoration in the EU and other international contexts. Furthermore, ecological restoration is one of the key actions for improving the supply of food and water security in the developing countries. Nordic initiatives in ecological restoration in developing countries can be an important contribution in this context

As mentioned before, emphasis on ecological restoration is increasing in a Nordic as well as a global context. The CBD-Aichi targets encourage restoration; the EU has regulations for when restoration is needed; in Norway, the new biodiversity act promotes restoration. In both Sweden and Norway the discussion about ecological compensation is increasing. For most of these compensation projects, ecological restoration would be the best answer. Furthermore, there is an increasing understanding of the beneficial effect of restoration in urban and near urban areas for outdoor activities and public health and there is an increasing interest in using ecological restoration to enhance the resilience of ecosystems to environmental hazards. All this will probably lead to more restoration projects in years to come. These activities offer new challenges and opportunities in Nordic and international contexts. In order to meet these challenges it is important to work constantly on improving and enhancing Nordic restoration work.

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Sammendrag og konklusioner

Denne rapport indeholder resultaterne af arbejdet i det nordiske netværk „RENO“ (Restoration of Damaged Ecosystems in the Nordic Countries). Netværket blev igangsat i 2009 som et tema-projekt finansieret af Nordisk Ministerråd. Netværket omfatter alle de nordiske lande og territorier med undtagelse af Grønland og Ålandsøerne.

Tolv institutioner har været involveret i netværket. Disse repræsenterer den videnskabelige verden, private og andre offentlige institutioner, som arbejder med økologisk restaurering, samt NGO-organisationer.

Netværkets primære opgave har været at skabe et overblik over og evaluere aktiviteter i de nordiske lande, som falder inden for økologisk restaurering med henblik på at forankre og sprede information. Der har været afholdt en international konference „Restoring the North“ i Island i 2011. Der er produceret mere end 30 publikationer af netværket og i forbindelse med konferencen, herunder statusrapporter fra de enkelte lande, en guide til økologisk restaurering og egentlige videnskabelige arbejder fra konferencen. Netværkets resultater har også været præsenteret på workshops, seminarer, korte kurser og i medierne samt på en verdensomfattende konference afholdt af den internationale sammenslutning for økologisk restaurering (SER, Society of Ecological Restoration). Medlemmer af netværket har endvidere deltaget i en arbejdsgruppe (Task-force IUCN-WCPA, International Union for Conservation of Nature-World Commission on Protected Areas) med henblik på at udarbejde en best practice guide for økologisk restaurering i beskyttede områder.

Netværkets centrale opgave har været at skabe et overblik over de omfattende restaureringsprojekter som gennemføres eller har været gennemført i de nordiske lande med henblik på at forankre disse i miljøpolitikken. Der er identificeret en række forhold, som vil kunne sikre yderligere udbredelse af økologisk restaurering:

- En stærk tilslutning til de såkaldte Aichi målsætninger om bevarelse af den biologiske diversitet, herunder målet om at restaurere mindst 15 % af „skadede“ økosystemer
- Argumenter for en langsigtet politik og lovgivningsmæssig forankring af økologisk restaurering
- Øget nordisk samarbejde om økologisk restaurering såvel i den Nordiske region som i EU og andre internationale sammenhænge
- Forbedret opfølgning og monitorering af økologiske restaureringsprojekter, herunder indførelse af „tilpasset drift“ for at forbedre projekternes implementering
- Udarbejdelse af bedre guide-materiale om økologisk restaurering med henblik på forbedret planlægning, integration og opfølgning af projekterne
- Forbedret uddannelsesniveau og målrettede opfølgende aktiviteter blandt aktørene inden for økologisk restaurering
- Sikring af en bred forankring og accept af økologiske restaureringsprojekter i befolkningen og blandt institutioner

Økologisk restaurering har potentialet til afgørende at bidrage til et forbedret globalt miljø, herunder stoppe tilbagegangen i biodiversiteten, modvirke igangværende klima ændringer, øge økosystemers evne til at imødegå miljøtrusler, og generelt forbedre livsbetingelserne for mennesker. RENO-netværket har afgørende forankret vores viden om økologisk restaurering i de nordiske lande og fremmet spredningen ny og eksisterende viden. Netværket håber på også fremover at kunne fremme økologisk restaurering og miljøpolitikken i EU og internationale institutioner.

Appendix 1. Participants in the ReNo network

Agricultural University of Iceland

- Ása L. Aradóttir, PhD, Professor
- Ólafur Arnalds, PhD, Professor and Dean, Faculty of Environmental Science

Arctic Centre, University of Lapland

- Bruce C. Forbes, PhD, Research Professor

Environmental Agency of Iceland

- Hildur Vésteinsdóttir, MS, Advisor

Faroese Museum of Natural History

- Anna Maria Fosaa, PhD, Director
- William Simonsen, Scientific Researcher
- Janus Hansen, MS, Head of Zoology Department

Hekla Forest

- Hreinn Óskarsson, PhD, Director

METLA – Finnish Forest Research Institute

- Anne Tolvanen, PhD, Professor

Metsähallitus

- Jussi Päivinen, PhD, Senior Planning Officer

NINA – Norwegian Institute for Nature Research

- Dagmar Hagen, PhD, Senior Scientific Researcher

Norwegian Public Road Administration

- Astrid Brekke Skrindo, PhD, Senior Consultant

Soil Conservation Service of Iceland

- Guðmundur Halldórsson, PhD, Network Leader
- Kristín Svavarsdóttir, PhD, Senior Scientific Researcher
- Þórunn Pétursdóttir, PhD student

Umeå University

- Christer Nilsson, PhD, Professor

University of Copenhagen

- Karsten Raulund-Rasmussen, PhD, Professor

Appendix 2. Publications from, or in conjunction with, the ReNo network

- Gunnarsdóttir, H. 2009. *Vistheimt Landsvirkjunar [Ecological restoration of Landsvirkjun]*. Landsvirkjun, LV-2009/109. (In Icelandic)
- Halldórsson, G., Aradóttir, ÁL, Svavarsdóttir, K. & Arnalds, Ó. 2009. *Vistheimt – endurheimt skemmdra vistkerfa á Norðurlöndum [RENO-Restoration of Damaged Ecosystems in the Nordic countries]*. Fræðaðing landbúnaðarins 2009 [The Annual Agricultural Forum], 532–533. (In Icelandic)
- Lind, L. 2009. *The strategies of river restoration: a review of 25 restoration projects*. Degree thesis in biology. Department of Ecology and Environmental Science, Umeå University, Umeå.
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- Aradóttir ÁL. & Halldórsson G. 2011. *Lessons from a century of restoration in Iceland*. Abstract presented on the 4th SER International World Conference on Ecological Restoration held in Mérida, Yucatán, México, August 21–25, 2011.
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- Similä, M. & Junninen, K. 2011. *Guide for forest habitat restoration and management*. Nature Protection Publications of Metsähallitus. Series B 157.
- Aapala, K. (ed.) 2012. *Guide book of peatland restoration in Finland*. Metsähallitus, Natural Heritage Services, Series A. in press.
- Aradóttir, AL., Petursdóttir, T., Halldórsson, G., Svavarsdóttir, K. & Arnalds O. 2012. *Drivers of restoration – lessons from a century of restoration in Iceland*. The 8th European Conference on Ecological Restoration, September 9–14, 2012 České Budějovice, Czech Republic: Near-Natural Restoration. Programme and Abstract Book, 0009, p. 26.
- Similä, M. & Junninen, K. 2012. *Ecological restoration and management in boreal forests – best practices from Finland*. Metsähallitus Natural Heritage Services.
- Svavarsdóttir, K., Hagen, D., Nilsson, C., Tolvanen, A., Aradóttir, AL., Raulund-Rasmussen, K. & Halldórsson G. 2012. *A regional assessment of ecosystem restoration: A case study on the Nordic countries*. The 8th European Conference on Ecological Restoration, September 9–14, 2012 České Budějovice, Czech Republic: Near-Natural Restoration. Programme and Abstract Book, P81, p. 114.
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- Morsing, J., Frandsen, IS., Vejre, H. & Raulund-Rasmussen, K. *Do the principles of ecological restoration cover EU LIFE Nature co-funded projects in Denmark?* Ecology and Society, submitted.
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ReNo

Restoration of damaged ecosystems in the Nordic countries

The ReNo network has consolidated knowledge on ecological restoration work in the Nordic region and facilitated exchange of this knowledge within and between the Nordic countries. Scientific papers, reports on the status of restoration, guidebooks on restoration, and analyses of ecological restoration in the area have been published as a result of the network. Ecosystem degradation is a problem in all the Nordic countries, but varies in nature, severity and scale between the countries. In order to counteract present and past ecological degradation, all the Nordic countries emphasise ecological restoration, but to various degrees. Ecological restoration has the potential to make a critical contribution for the benefit of the global environment and human living conditions. The ReNo network recommends that this important activity should be prioritized in Nordic environmental policy.

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