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monitoring results

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Habitat restoration of coniferous forests on glaciofluvial eskers – four-year results

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Abstract

European countries have made commitments to conservation of habitats of concern listed in Annex 1 of the European Council Directive 92/43/EEC (21 May 1992) on the conservation of natural habitats and of wild fauna and flora (Council Directive, 1992). Much of present area of forest habitats of concern has been degraded, as natural processes in forests are not compatible with the main goal in commercial forests on wood productivity. The present work was focused on the EU protected habitat 9060 “Coniferous forests on, or connected to, glaciofluvial eskers”. The typical plant communities of this habitat are well lit under a sparse canopy and often contain rare and protected sun-loving plants. Within the LIFE project “National Conservation and Management Programme for Natura 2000 sites in Latvia”, in winter 2013–2014 restoration of two pine stands on an esker system was conducted in the Razna National Park. The restoration attempted to create the natural structure of this habitat by reducing shading of target sun-loving plants by partial harvest of trees and creation of patches of exposed mineral soil. The aim of the present work was to assess the effects of restoration using a Before–After treatment (BA) experimental design. In general, management had minimal effect on restoration of the target plant community. Development of a new *Pinus sylvestris* cohort was initiated, which is expected to increase shading in the future. Further restoration of esker habitat should be employed

only when the target sun-loving species are still present, as seed dispersal from neighbouring stands and establishment will likely not be successful. Also, creation of patches with exposed mineral soil requires more complete scarification by mechanical equipment or by burning.

Keywords: boreal, light, partial harvest, sun-lit, scarification, vegetation

Abbreviations: MRPP, multiple response permutation procedure

Introduction

Land-use change has been the main cause of loss of biological diversity globally (Millennium Ecosystem Assessment 2005). Most of the forest area in the temperate zone of Europe was cleared for agriculture and for exploitation of wood during the Holocene, and much of the remaining woodland is post-agricultural secondary forest (Kaplan et al. 2009). Forests in the boreal and temperate zones that have not been affected by human use practically no longer exist (Brang 2005). Forest area is larger (>40%) in the boreal forest zone of Europe (Forest Europe 2011). However, these are now mostly industrial forests aimed at high productivity, and they lack natural structures like coarse woody debris and canopy gaps of variable size that are needed as habitat for many specialist species (Brūmelis et al. 2011).

Much has been learned about the reasons for loss of biological diversity and on means of management to halt this process (Villard, Jonsson 2009), but global incentives to halt the decline have failed (Butchart et al. 2010). The Aichi targets of the Convention of Biological Diversity (2010) aim for an increase of area of protected territories to 17% by 2020, and that 15% of degraded habitat needs to be restored. These targets are based on evidence that many forest specialist species require at least 20–30% suitable habitat in a landscape for survival, which can be most efficiently achieved by focusing

conservation efforts in aggregations of habitats, and not throughout the countryside (Hanski 2000).

Natural disturbances like fire, insect damage and wind at different scales create patches of different size and structures, which create large spatial heterogeneity (Kuuluvainen 2002; Shorohova et al. 2002). The focus of habitat restoration in the boreal zone is on emulation of natural disturbance (Long 2009; Kuuluvainen, Grenfell 2012). In Latvia, restoration of forest habitat has been conducted within several EU LIFE and other projects, but regular and thorough monitoring of the results of restoration, if conducted after end of the project periods, is generally not published in scientific journals. However, the knowledge gained by practitioners and others in habitat restoration in Latvia and other countries has been reviewed and used to prepare the Protected Habitat Conservation Guidelines for Latvia (Ikaunieca 2017). Most, if not all, of the future funding in Latvia on habitat restoration will be focused on habitats of concern listed in Annex 1 of the European Council Directive 92/43/EEC (21 May 1992) on the conservation of natural habitats and of wild fauna and flora (Council Directive, 1992). The present work was focused on the EU habitat of concern 9060 “Coniferous forests on, or connected to, glaciofluvial eskers”. The main characteristic of this type is hills or ridges of glaciofluvial origin that run parallel to past glacial ice movement. The forests are on slopes with coarse sandy soils, and area more lit and open than in lowland forests, which creates habitat for sun-loving species, including rare species like *Pulsatilla patens*, *Dracocephalum ruyschiana*, and *Onobrychia arenaria* (Bambe 2013). Historically, the main disturbance that maintained an open canopy is considered to be fire (Ikaunieca 2017). However, it needs to be noted that most fires in Europe in the Holocene have been human-caused rather than of natural origin (Wallenius 2011; Dietze et al. 2018;). The fire frequency

in the past 100 years has dramatically decreased due to lack of utilization of fire for land management and fire suppression. As a result, increased shading and build up of an organic layer by shrub and subcanopy layers of *Picea abies* (Prescott et al. 2000; Augusto et al. 2002) has caused degradation of the values of sun-lit open habitats (Similä, Junninen 2013). Possible restoration measures to reduce shading and remove the organic layer are controlled burning, cutting of shrubs and some trees, and raking and removal of the organic layer in patches (Ikauniece 2017).

The aim of the present work was to assess the effects of restoration by shrub and tree cutting, and also removal by raking of the organic layer in dry pine mixed forest on an esker system. This was done using a replicated Before–After treatment (BA) experimental design.

Materials and Methods

Study area

The study was conducted in the Razna National Park, situated in eastern Latvia in the central part of the Latgale Upland. The average annual temperature is -7.5°C in January and $+16.8^{\circ}\text{C}$ in July (Rove 2009). Restoration was conducted on glaciofluvial eskers, which cross the national park area from northeast to southwest. Two stands (Stands 2 and 4) were selected for the restoration in the forest management unit 122. The selected stands were on sandy slopes dominated by *P. sylvestris* with *P. abies* entering the canopy.

Field data

In 2013, 9 representative, permanent monitoring plots (each 10x10 m) were established in each of the two stands selected for the restoration. Plot location was marked by permanent paint on a large *P. sylvestris* on the upper side of the plot on the

slope, in the right corner of the plot (looking down the slope). Precise location of plot sides was checked from photographs of the plots taken when first established.

Coordinates of plots are given in Table 1. The sampled area covered about 9% of each stand. Habitat restoration was conducted in winter 2013–2014 by cutting and removal of all *P. abies* in the canopy and understory. All branches were removed. In addition, in autumn 2014 (after monitoring in that year), in the 100 m² plots in Stand 4, the mineral soil was uncovered by removing the moss and soil O-horizon layers by hand rake in patches. The mean area uncovered in plots was 11.8 m² (range 0–20.2 m²); thus, about 10% of the stand area.

Table 1. Plot coordinates (LKS-92 geographic coordinate system) in the Razna National Park, Forest Management Unit 122.

Stand 2	X coordinate	Y coordinate
1	708220	6234674
2	708225	6234655
3	708222	6234590
4	708197	6234613
5	708205	6234636
6	708194	6234669
7	708183	6234676
8	708187	6234634
9	708182	6234620
Stand 4		

The vegetation was described in summer in 2013 (before cutting), 2014 (before raking conducted in that year), 2015 and 2017. Percentage cover of all species (vascular plants and ground bryophytes) was determined. Plant species nomenclature followed Priedītis (2014) for vascular plants and Āboliņa (2001) for bryophytes. Diameter at 1.3 m height of all trees was measured in 2013 before cutting and 2014 after cutting. Counts were made of all established seedlings in each year of monitoring

1	708470	6234676
2	708439	6234675
3	708415	6234669

4	708448	6234663
5	708398	6234636
6	708384	6234641
7	708414	6234629
8	708405	6234629
9	708432	6234624

Data analysis

Differences on composition of plant communities was assessed by detrended correspondence analysis. Determination of significant differences in species cover and total moss cover between years and stands was done using indicator species analysis. These analyses were conducted using the program PCord version 5.0.

Results

Tree layers

In Stand 2, the mean basal diameter of *P. abies* decreased from 19.1 to 6.6 m²/ha due to tree harvest, and in Stand 4 from 5.3 to 0.6 m²/ha (Table 2). Part of the *P. abies* and *Betula pendula* subcanopy was retained to prevent drastic change in light levels (Table 3). In Stand 4, almost all of the *P. abies* was cut. Aside from a few *P. sylvestris* trees in the 10.1–20.0 cm diameter class, all others were retained. The retained amount of deciduous tree species was very low.

Table 2. Tree basal area (m²/ha) before and after cutting of subcanopy and saplings.

		<i>Picea abies</i>	<i>Pinus sylvestris</i>	<i>Betula pendula</i>	<i>Populus tremula</i>
Stand 2	2013	19.1	27.0	1.6	1.0
	2014, after management	6.6	25.0	1.6	1.1
Stand 4	2013	5.3	42.1	1.0	0.00
	2014, after management	0.6	41.2	1.0	0.00

Table 3. Average tree density (number/ha). Year 2013 represents the control time before cutting.

Stand 2	2013				2014, after management			
DBB (cm)	<i>Picea abies</i>	<i>Pinus sylvestris</i>	<i>Betula pendula</i>	<i>Populus tremula</i>	<i>Picea abies</i>	<i>Pinus sylvestris</i>	<i>Betula pendula</i>	<i>Populus tremula</i>
<5.1	189	0	11	0	56	0	0	0
5.1–10	133	0	0	0	0	0	0	0
10.1–20.0	367	22	11	0	0	11	11	0
20.1–30.0	144	33	11	0	56	33	11	0
30.1–40.0	167	78	11	11	33	78	11	11
>40	100	111	0	0	0	111	0	0
Stand 4								
<5.1	456	0	33	0	0	0	22	0
5.1–10	122	0	44	0	0	0	44	0
10.1–20.0	189	56	67	0	0	33	67	0
20.1–30.0	33	122	0	0	1	144	11	0
30.1–40.0	0	256	0	0	0	222	0	0
>40	0	67	0	0	0	78	0	0

After opening of the overstory canopy, abundant regeneration of all tree species occurred. Establishment of *P. sylvestris* was particularly high reaching 2667 seedlings in 2017 in Stand 4 where the moss and soil O-horizon layers and been removed in patches (Table 4).

Table 4. Density of tree seedlings (number/ha). Year 2013 represents the control time before cutting. The moss and organic layer was removed just after monitoring in 2014.

	Density of tree seedlings (number/ha)			
	2013	2014	2015	2017
Stand 2				
<i>Picea abies</i>	0	0	78	89
<i>Pinus sylvestris</i>	0	0	444	1289
<i>Betula pendula</i>	0	0	200	378
<i>Populus tremula</i>	0	0	356	233
Stand 4				
<i>Picea abies</i>	0	0	178	211
<i>Pinus sylvestris</i>	0	0	689	2667
<i>Betula pendula</i>	0	0	189	111
<i>Populus tremula</i>	0	0	89	0

Changes in vegetation

Detrended correspondence analysis (Fig. 2) of plant community data showed clusters of the two stands with considerable overlap. In addition, Multiple Response Permutation Procedure ($p < 0.01$) and Indicator Species Analysis (Table 5) showed significant differences among the studied stands in composition of the plant communities. Among the moss species, *Hylocomium splendens* had greater cover in Stand 2, and *Pleurozium schreberi* and *Ptilium crista-castrensis* in Stand 4. The cover of *Vaccinium vitis-idaea*, *Calluna vulgaris* and *Pteridium aquilinum* was higher in Stand 4, and *Rubus saxatilis* in stand 2.

Table 5. Indicator Species Analysis of plant communities in plots of studied stands. Only species with indicator values greater than 40 are shown.

Species	Stand with maximum cover	Indicator value	p level
<i>Calluna vulgaris</i>	4	41.3	0.019
<i>Pleurozium schreberi</i>	4	66.2	0.0006
<i>Hylocomium splendens</i>	2	67.2	0.0002
<i>Rubus saxatilis</i>	2	67.9	0.0002
<i>Vaccinium vitis-idaea</i>	4	69.5	0.0002
<i>Ptilium crist-castrensis</i>	4	93	0.0002
<i>Pteridium aquilinum</i>	4	100	0.0002

The only observed sun-loving species that were targets of the management were *P. patens*, a protected species found in one plot in Stand 2 before and after management, and *Arctostaphylos uva-ursi* in one plot in stand 4 after management. Another protected species, *Lycopodium annotinum*, was found in two plots of Stand 4 before and after management.

After the employed management, there were some new species that appeared in 1–3 plots of Stand 2. These were all common species of forest and/or open habitats, like *Fragaria vesca*, *Melica nutans*, *Solidago virgaurea*, *Rumex acetosella* and *Senecio jacobea*. The only arriving species in Stand 4 were *A. uva-ursi* in one plot and *Festuca ovina* in three plots. Despite these changes, MRPP and Indicator Species Analysis showed no significant differences in composition of plant communities between the times of plot monitoring, even in cover of any of the moss species after removal of patches of moss and the O horizon. However, MRRP showed significant differences between years in total moss cover (not herb layer cover), but only in Stand 4. In Stand 4, the total cover of moss was significantly less in 2014 (after cutting and before raking) and 2015 (after raking) than in 2013, but cover in 2013 and 2017 did not significantly differ (Fig. 3).

Discussion

Previous restoration attempts in habitat management in Finland by removal of shading trees and exposure of the mineral horizon have been successful in ensuring continuity of sunlit habitats and their respective plant communities (Similä, Junninen 2013). However, the employed habitat management in the present study by creating sun-lit conditions and partial removal of the ground layer with the soil O horizon did not achieve the goal of colonization of target sun-loving plant species. Rather, common plant species of open habitats colonized the stands. As exceptions regarding sun-loving species, the opening of the canopy might have improved conditions for the one *P. patens* individual that was found before management, and the newly arriving *Arctostaphylos uva-ursi* individual. Seeding experiments with *P. patens* have shown successful establishment after mechanical removal of the moss and O-horizon layers and particularly after controlled burning (Kalamees et al. 2005). As appropriate conditions were created by restoration, the unsuccessful results can be partly explained by dispersal limitation. Target species like *P. patens*, *D. ruyschiana*, and *O. arenaria* were observed within forest stands, including in a clearcut, located near the managed sites at distances of a few 100 m to 1 km. However, these distances were likely too far for successful dispersal and establishment.

Another reason for unsuccessful colonization of the target species might be rapid regrowth of the moss layer, as the total moss cover four years after management did not differ from that before management. The growth of *P. schreberi* from vegetative propagules on various exposed patches can be particularly rapid (Frego 1996), which would be expected to retard establishment in cases when seed germination did occur. The main factor limiting establishment of, for example *P. patens*, is formation of a thick litter and moss layer, rather than light conditions (Kalamees et al. 2005). It is likely that removal by raking of the past build-up of the O horizon by accumulation of *P. abies* litter (Prescott et al. 1996) was insufficient, and more complete scarification using heavy equipment or by burning would be required for a successful restoration outcome.

A new cohort of *P. sylvestris* established in both stands, with greater density when the ground layer was removed. Destruction of the vegetation cover (ericoid shrubs, feather moss) and availability of a seed source are required for successful establishment of *P. sylvestris* (Nilsson et al. 1996; Engelmark et al. 1998; Kuuluvainen, Juntunen, 1998). Thus, the formation of new shrub layer of a *Pinus*

sylvestris with other tree species was not surprising, and will promote shading of the ground layer in the future. The created multi-cohort structure of *Pinus sylvestris* emulates that formed by natural disturbances (Brūmelis et al. 2005), and in this respect the employed management can be considered to have been successful in improving the naturalness of the stands (Brūmelis et al. 2011). However, without formation of large gaps in the overstory *Pinus sylvestris*, which was not done in the restoration by cutting, after a period of slow growth further survival of this light-requiring tree in the understory is not expected (Gaudio et al. 2011).

Stand replication was not employed in the experimental design, as the study was restricted to situation that was available in the restoration project. Also, the two stands in which the harvest was implemented appeared to initially differ. The cover of species like *V. vitis-idaea* and *Calluna vulgaris*, which require more open conditions, was higher in Stands 2. This limits comparison of the two treatments. In addition, there was no control treatment. However, we consider that the comparison of vegetation composition before and after the treatments does allow to offer some general recommendations regarding the restoration conducted. The study showed that efficient management of esker and other sunlit sites should be considered only when the target species are still present (Similä, Junninen 2013). More complete scarification of the O horizon is needed, and perhaps, artificial seeding needs to be implemented. The results can also be used in planning of restoration in other boreal habitats where cutting of the shrub layer is considered, albeit only regarding plant communities and not other organism groups. It is important to report also lack of effects due to habitat management, as this information is required in planning management for conservation of biological diversity.

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Figure captions.

Fig. 1. Map showing location of the study area in Latvia

Fig. 2. Detrended correspondence ordination of plots. Stands are indicated.

Fig. 3. Mean total moss cover in stands in the study period. Significant differences (indicator species analysis) are shown by different letters.

Fig. 1.

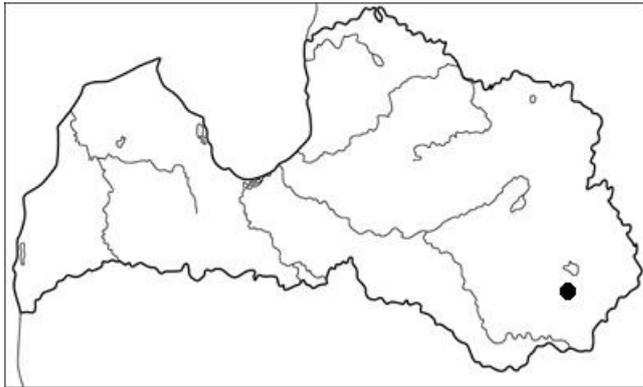


Fig. 2

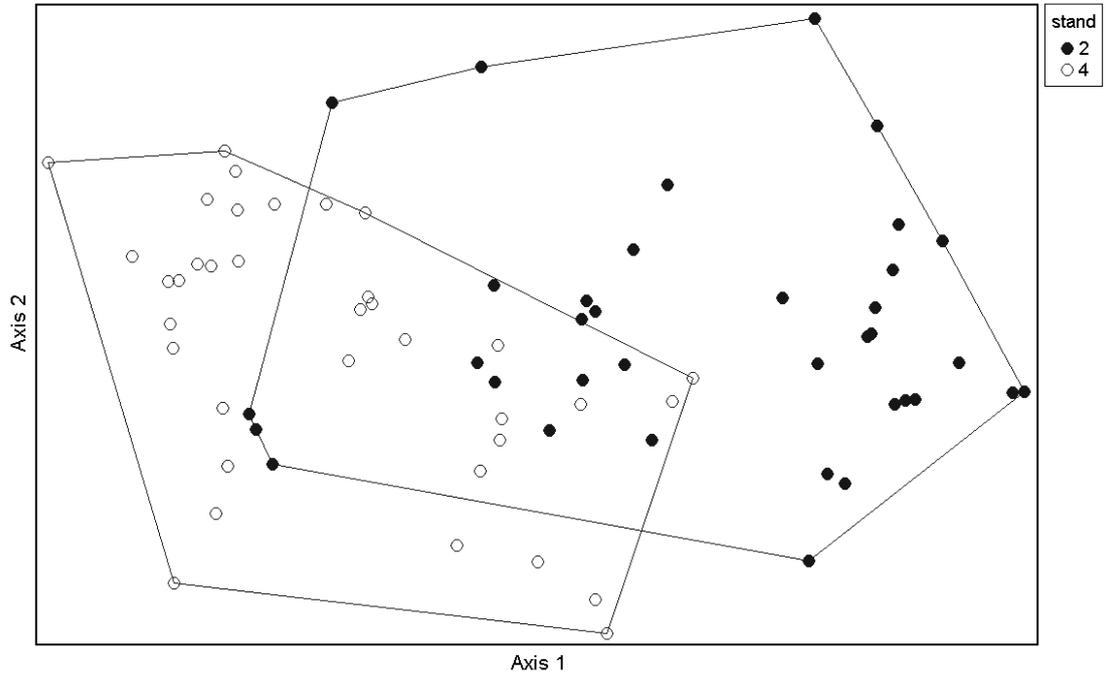


Fig. 3.

