Environmental and Experimental Biology (2020) 18: 77–82
http://doi.org/10.22364/eeb.18.07

Original Paper

ISSN 2255-9582

Ecological restoration by canopy thinning in a *Quercus robur* forest can cause development of a dense shrub layer

Guntis Brūmelis[1]*, Jolanta Rieksta[2,3], Egita Zviedre[1], Sandra Ikauniece[4]

[1]Faculty of Biology, University of Latvia, Jelgavas 1, Rīga LV–1004, Latvia
[2]Terrestrial Ecology Section, Department of Biology, University of Copenhagen, Universitetsparken 15, Copenhagen DK–2100, Denmark
[3]Center for Permafrost (CENPERM), Department of Geosciences and Natural Resource Management, University of Copenhagen, Øster Voldgade 10, Copenhagen K DK–1350, Denmark
[4]Nature Conservation Agency, Baznīcas 7, Sigulda LV–2150, Latvia

*Corresponding author, E-mail guntis.brumelis@lu.lv

Abstract

The area of *Quercus robur* forest stands in Northern Europe is extremely low due to the legacies of forest management targeted on coniferous tree species and past land conversion on rich soils to agriculture. These stands are characterized by a unique flora and fauna and therefore they are important in the network of protected areas. It is well known that *Q. robur* will not regenerate under a closed canopy. Thus, these stands are being gradually replaced in succession by shade-tolerant species like *Picea abies*, which can alter soil conditions. Removal of encroaching trees around *Q. robur* to maintain the typical habitat conditions is commonly practiced in Northern Europe, but the results of these restoration activities are inconclusive, and not always published when conducted in a practical conservation framework. In Latvia, such restoration of *Q. robur* stands has commonly been implemented in protected areas, but no publications are available on achieved results. In a restoration project setting, we determined effects of removal of *P. abies* in the subcanopy and canopy around old *Q. robur* on tree regeneration and composition of the herb layer. Within a five-year period after management, the created openings were invaded first by generalist species common in open habitats. There was a continuous increase in abundance of the shrub *Rubus idaeus*, which reached 100% in all plots. There was minimal regeneration of *Q. robur*, while establishment of *Populus tremula* occurred. Development of a herb layer was inhibited. However, it is expected that this shrub phase will end in the short- to long-term priod of time.

Key words: forest management, inhibition model, nemoral communities, *Picea abies, Quercus robur*, understorey vegetation.
Abbreviations: DBH, diamater at breast height.

Introduction

The legacies of intensive forest management in Northern Europe have caused homogenization of forest landscape by decreasing amounts of natural disturbances (Brūmelis et al. 2011a). A common way to attempt to bring back natural structures and processes in boreal forest has been by disturbance emulation, for example, by creation of dead wood (Halme et al. 2013). In temperate forest, four types of management for conservation have been used: (1) minimal intervention, (2) traditional management to create cultural landscapes, such as wooded meadows, (3) non-traditional management, like disturbance emulation, or focus on a target tree species, and (4) management aimed at focal species (Götmark 2013). These types of management are interrelated. For example, the latter three are implemented by cutting of trees and shrubs around old *Quercus robur* to improve light conditions required for establishment of *Q. robur* seedlings (Götmark 2007), and for saproxylic insects (Widerberg et al. 2018).

In the transition zone between the boreal and temperate forest zones of Europe, land conversion to agricultural land-use and wood industry focused on coniferous tree species has caused depletion of broad-leaved forests, and in Latvia the relative area of forest dominated by *Q. robur* is less than 1% (Rendenieks et al. 2019). It is known that Q. *robur* seedlings will not establish under a Q. robur canopy (Brūmelis et al. 2017), and in many areas *Q. robur* is being naturally replaced by *Picea abies* or *Tilia cordata* in the tree canopy (Brūmelis et al. 2011b; Kokarēviča et al. 2016). Increase in amounts of *P. abies* litter will cause accumulation of organic matter and decrease of pH value (Vesterland, Raulund-Rasmussen 1998; Bonifacio et al. 2008), which will hinder colonization and growth of nemoral species (Brunet et al. 1997; Brunet et al. 2011).

Considering the small area of *Q. robur* stands and the risk of their loss or degradation through natural succession, a typical conservation measure practiced is cutting of *P. abies* around old *Q. robur*. However, the results of conservation thinning are inconclusive and in Sweden it has been reported that the thinning favours growth of shrubs after 8 to 10 years and not oak regeneration (Götmark 2013). While this type of management is widely implemented in protected areas in Latvia, we could not find any publications that presented the results of the effects of this type of management, and few are available from other regions (Götmark et al. 2005; Götmark 2007; Kint et al. 2009; Simila, Junninen 2012). Therefore, the results of ecological restoration by improving light conditions around old *Q. robur* cannot be objectively assessed, particularly as documented field conditions before the restoration do not exist.

The aim of the study was to conduct a before-after-control-impact experiment to evaluate effects of removal of *P. abies* in the subcanopy and canopy around old *Q. robur* on tree regeneration and composition of the herb layer. The cutting was conducted in an protected oak forest habitat (EU habitat 9160) in the Nature Reserve "Paņemūnes meži", with the aim to increase its conservation value. It was hypothesized that the restoration would increase regeneration of *Q. robur* and promote development of a nemoral plant community.

Materials and methods

Site description

The study site is located within the Nature Reserve "Paņemūnes meži", which was established for conservation of valuable forest habitat and for protected bird species. The reserve is located in Brunavas pagasts of Bauska municipality in the Zemgale Lowland. The soils in area are characterized as rich soils with free carbonates. Mean air temperature is –5 °C in January and 17.0 to 17.5 °C in July.

The restoration was carried out in Stand 5 ("nogabals" in Latvian) of Forest Management Unit 172 ("kvartāls" in Latvian), geographical decimal coordinates: 56.304240, 24.427142. The selected forest stand was a Myrtilloso-polytrichosa site type on rich wet mineral soil. The canopy was dominated by *Q. robur*, *Picea abies* and *Betula pendula*. Six treatment plots with radius 25 m were designated for harvest of *P. abies*. The center of each plot was taken as a large *Q. robur*, and marked by red permanent paint. In addition, three plots were selected at the edge of the stands to serve as control plots. Replication of stands was not employed in the study design of the project, as it was a pilot restoration activity.

Forest management

Forest management by removal of trees shading *Q. robur* was done by SIA „Meža un koksnes produktu pētniecības un attīstības institūts". In winter 2013 – 2014, *P. abies* trees in the canopy, subcanopy and sapling layers were cut by chain saw within a 25-m radius around the centre of plots. Wood and all branches were removed from the stand with a small track forwarder. The small equipment was selected to avoid ground disturbance. However, deep ruts were made in circles around plots and along the strip roads between plots and to the landing. An area of about 2 ha was cut, which included the strip roads used for wood removal.

Field data

In September 2013 (before management) and in July 2014, 2015 and 2018, data was collected on vegetation in plots within a 15-m radius around the centre of plots The smaller plot size was chosen to avoid edge effects and the ruts formed by wood removal. In these plots, diameter at 1.3-m height (DBH) of all trees was measured and number of tree stems by species was determined. Cover of all species was estimated in percent for all understory layers.

Data analysis

Information on plant strategies (Grime 1977) of plants was taken from the database BIOLFLOR (Klotz et al. 2002) and seed dispersal agent from ECOFLORA (Fitter, Peat 1994). Differences in species richness and cover of shrubs between years was tested by ANOVA with Tukey's post hoc test using JASP version 0.9.2. Indicator species analysis in PCORD 5.0 was used to identify indicator species in the herb layer for years and between control and managed sites.

Results

Tree species

Before management, basal area and density of stems by DBH were similar in managed and control plots. Tree harvest lowered the mean basal area of *P. abies* in plots from 14.5 to 0.1 m^2 ha^{-1} and number of *P. abies* stems decreased from 500 to 2 (Table 1). The shrub layer of *P. abies* was completely removed. Other tree species were not cut.

Before management, the number of trees with height < 1 m was low in both managed and control plots (Table 2). In 2014 regeneration of *Populus tremula* had occurred in the managed plots, reaching about 1300 stems ha^{-1} compared to 1 stem ha^{-1} in 2013. Some regeneration of *P. tremula* also occurred in control plots.

Shrub layer species

Among shrub layer species, the cover of Rubus idaeus increased in the managed plots and five years after management in 2018 it had become the dominant species with 100% cover (Fig. 1). Cover of tall shrub species like *Corylus avellana* and *Sorbus aucuparia* did not significantly differ between years. The cover of these shrub species did not significantly differ between years in control plots, nor between control and management plots in 2013.

Table 1. Basal area and mean density of trees (number ha^{-1}) in DBH classes in plots before and after management. BA, basal area

	2013 (before management)				2014 (after management)			
	Picea abies	*Quercus robur*	*Betula pendula*	*Populus tremula*	*Picea abies*	*Quercus robur*	*Betula pendula*	*Populus tremula*
Control plots								
BA (m^2 ha^{-1})	14.8	7.3	10.8	1.8	14.8	7.3	10.8	1.8
DBH (cm)								
5.1 – 10.0	42	0	0	0	42	0	0	0
10.1 – 20.0	255	0	14	0	255	0	14	0
20.1 – 30.0	193	0	52	0	193	0	52	0
30.1 – 40.0	19	19	71	0	19	19	71	0
> 40.0	5	24	14	9	5	24	14	9
Managed plots								
BA (m^2 ha^{-1})	14.5	10.9	11.4	2.9	0.1	10.9	11.4	2.7
DBH (cm)								
5.1 – 10.0	31	0	0	0	0	0	0	0
10.1 – 20.0	248	0	9	0	0	0	9	0
20.1 – 30.0	191	0	66	0	2	0	45	0
30.1 – 40.0	17	9	37	0	0	12	57	0
> 40.0	2	62	19	14	0	57	24	14

Herb layer species

Indicator species analysis (Table 3) showed significantly higher cover of *Polygonum hydropiper* in the first year (2014) after management, the only year when this species was recorded. This competitive-ruderal species occurred mostly in wet ruts created by equipment used to remove cut trees. *Artemisia vulgaris, Coronaria flos-cuculi, Mentha arvensis, Moeringia trinervia* and *Ranunculus repens* were significant indicator species two years after management (2015). These species have a competitor or intermediate competitive-stress tolerant-ruderal strategy, and each has various seed dispersal agents, including man, vehicles and animals. Cover of *Oxalis acetosella*, a significant indicator species, increased from 2014 to 2015 and was lower in 2018. This species has short-distance ballochorous seed dispersal. Despite the differences in species composition, species richness did not significantly differ between years (Fig. 2).

Discussion

The aim of management to promote development of nemoral plant communities and regeneration of *Q. robur* by creation of *Q. robur* open woodland was not achieved in a five-year period. Tree regeneration in the managed plots was dominated by *P. tremula*. Partial cutting in broad-leaved stands is initially associated with an increase in diversity of the herb layer due to establishment by seed dispersal and from the seed bank, and the increased availability of resources for light-demanding species (Götmark et al. 2005). In our study species richness had increased two years after management, but then had decreased after five years, although these changes were not significant. Ecological succession in plots after management was characterized by colonization of habitat generalist species that are typical of various open habitats, such as forest

Table 3. Mean density (number ha^{-1}) of trees < 1-m height in managed and control plots

Species	2013	2014	2015	2018
Control plots				
Betula sp.	0	0	0	0
Fraxinus excelsior	0	0	0	0
Quercus robur	1	9	0	0
Populus tremula	1	9	75	0
Picea abies	0	0	0	0
Managed plots				
Betula pendula	0	0	12	0
Fraxinus excelsior	0	0	2	0
Quercus robur	1	28	26	17
Populus tremula	1	1297	578	127
Picea abies	1	35	0	17

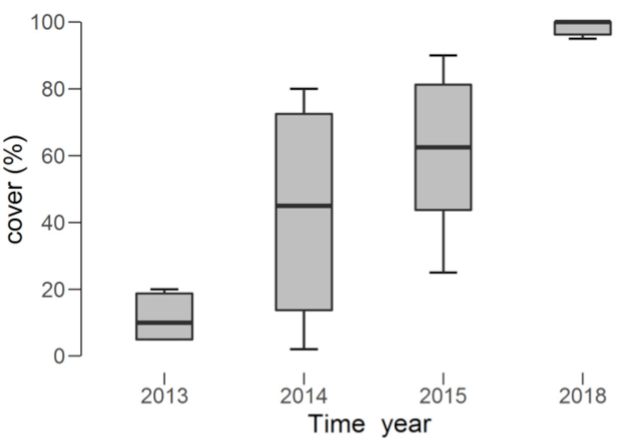

Fig. 1. Boxplot (median, interquartile and maximum) of cover (%) of *Rubus idaeus* in managed plots after harvest (2014 – 2018). Data for 2013 represents time before harvest.

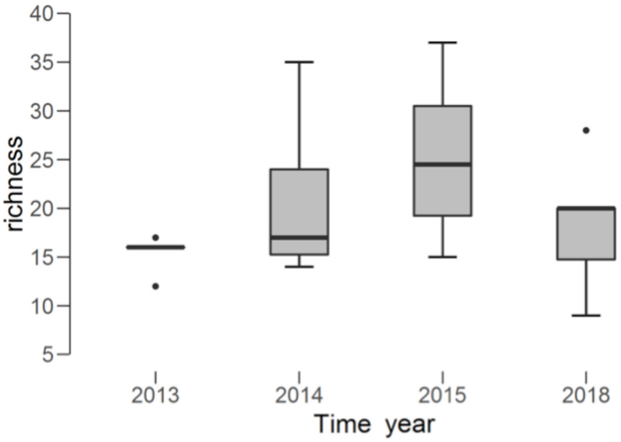

Fig. 2. Species richness of the herb layer in plots before (2013) and after management (2014 – 2018).

edges and ditches. The opening of the tree canopy and disturbance to the ground layer allowed rapid invasion of *P. hydropiper*, an annual plant characteristic of wet and moist soils. This species quickly invaded wet microsites created by heavy machinery during removal of *P. abies* wood and branches and dispersal of seed was likely facilitated by the track forwarder employed. *P. hydropiper* is an opportunistic species with a competitive ruderal strategy (Klotz et al. 2002), which has been observed to prefer disturbed parts of walking trails (Roovers et al. 2004). Its abundance rapidly decreased with colonization of species with a competitive strategy, like *Artemisia vulgaris, Deschampsia caespitosa, Mentha arvensis*, as well as species with an intermediate competitive/stress tolerant/ruderal strategy (*Coronaria flos-cuculi, Moeringia trinervia* and *Ranunculus repens*; ecological strategies from Klotz et al. 2002). These common species of various habitats like open forests, wet and moist grasslands, shrub lands and ditch edges responded to the increased light resources available after cutting and had colonized the plots two years after management.

The succession culminated in the five years with dominance by *Rubus idaeus*, which commonly colonises forest stands after different types of disturbance (Meilleur et al. 1994). Tree regeneration under this competitive species is unlikely to happen due to low light availability under the *R. idaeus* canopy (Gaudio et al. 2008). This observed stage of dominance by a long-lived species (*R. idaeus*) that replaced short-lived species is consistent with the inhibition model of succession (Foster, Tilman 2000), whereby early colonising species inhibit the establishment and development of other individuals (Connell, Slatyer 1977). The abundance of early colonizing species like *R. idaeus* has been observed to decrease after disturbance (Ulanova 2000), and it may persist for more than 10 years (Widen et al 2018). In a longer period we can expect that the cover of *R. idaeus* will decrease, but in a previous study, 8 to 10 years after partial cutting in *Quercus* forest, regeneration of shrubs like *Corylus, Rhamnus, Lonicera* was observed (Götmark 2013). Due to increased shrub cover in the future, the observed low regeneration of *Q. robur* in the fifth year of management might not result in its successful growth and survival.

The experimental design of our study was restricted to only one stand, as the restoration was conducted as a pilot restoration activity in larger project targeted at practical conservation of biological diversity, and not scientific

Table 3. Herb layer species with significantly higher indicator value (indicator species analysis) in years before and after management. Ecological strategy (C, competitor; S, stress tolerant; R, ruderal) and seed dispersal agent are also given

Species	2013	2014	2015	2018	*p*	Ecological strategy	Dispersal type
Oxalis acetosella	12	30	37	17	0.028	CSR	ballochorous
Polygonum hydropiper	0	67	0	0	0.006	CR	unspecialized
Artemisia vulgaris	0	2	52	8	0.029	C	unspecialized
Coronaria flos-cuculi	0	0	50	0	0.038	CSR	unspecialized
Deschampsia cespitosa	0	0	52	25	0.021	C	unspecialized
Mentha arvensis	0	0	50	0	0.038	C	unspecialized
Moehringia trinervia	0	8	61	15	0.003	CSR	unspecialized
Ranunculus repens	0	1	62	0	0.021	CSR	unspecialized

research. This does not allow wide extrapolation of the results, but the results of restoration need to be monitored and results published for adaptive management, i.e. to learn from mistakes and successes. We present only the results of restoration after five years, which is a short time in a forest ecosystem to allow to conclude on long-term changes. However, the monitoring work will be continued.

Conclusions

The aim of the restoration by removal of *P. abies* in the subcanopy and canopy around old *Q. robur* was to allow regeneration of *Q. robur* and promote development of nemoral plant communities. In a five-year period after the restoration, we observed minimal regeneration of *Q. robur*. Rather, establishment of *P. tremula* occurred, which can be expected to enter higher canopy layers in the future. Invasion of generalist species common in open habitats was observed and the plant community was dominated by a dense shrub layer with *R. idaeus*, which inhibited succession. The monitoring needs to be continued to determine if this shrub phase will end in the short- to long-term.

Acknowledgements

The study was funded by the EU LIFE project NAT-PROGRAMME. Appreciation is given to the Latvian Nature Conservation Agency for organization of the project, to AS "Latvijas valsts meži" for organization of the restoration activities and to SIA „Meža un koksnes produktu pētniecības un attīstības institūts" for carrying out the cutting.

References

Bonifacio E., Caimi A., Falsone G., Trofimov S.Y., Zanini E., Godbold D.L. 2008. Soil properties under Norway spruce differ in spruce dominated and mixed broadleaf forests of the southern taiga. *Plant Soil* 308: 149–159.

Brūmelis G., Jonsson B., Kouki J., Kuuluvainen T., Shorohova E. 2011a. Forest naturalness in Northern Europe: Perspectives on processes, structures and species diversity. *Silva Fenn.* 45: 807–821.

Brūmelis G., Dauškane I., Ikauniece S., Javoiša B., Kalviškis K., Madžule L., Matisons R., Strazdina L., Tabors G., Vimba E. 2011b. Dynamics of natural hemiboreal woodland in the Moricsala Reserve, Latvia: The studies of K.R. Kupffer revisited. *Scand. J. Forest Res.* 26: 54–64.

Brūmelis G., Ikauniece S., Voiceščuka A., Artistova A., Treimane A., Dauškane I., Elferts D., Tjarve D. 2017. Tree regeneration in noble broadleaved tree stands at their northern limit: Implications for conservation management. *Environ. Exp. Biol.* 15: 275–282.

Brunet J., Falkengren-Grerup U., Rühling Å., Tyler G. 1997. Regional differences in floristic change in south Swedish oak forests as related to soil chemistry and land use. *J. Veg. Sci.* 8: 329–336.

Brunet J., Valtinat K., Mayr M.L., Felton A., Lindbladh M., Bruun H.H. 2011. Understory succession in post-agricultural oak forests: Habitat fragmentation affects forest specialists and generalists differently. *For. Ecol. Manage.* 262: 1863–1871.

Connell J.H., Slatyer R.O. 1977. Mechanisms of succession in natural communities and their role in community stability and organization. *Am. Nat.* 111: 1119–1144.

Fitter A.H., Peat H.J. 1994. The ecological flora database. *J. Ecol.* 82: 415–425.

Foster B.L., Tilman D. 2000. Dynamic and static views of succession: Testing the descriptive power of the chronosequence approach. *Plant Ecol.* 146: 1–10.

Gaudio N., Balandier P., Marquier A. 2008. Light-dependent development of two competitive species (*Rubus idaeus*, *Cytisus scoparius*) colonizing gaps in temperate forest. *Ann. For. Sci.* 65: 1–5.

Goris R., Kint V., Haneca K., Geudens G., Beeckman H., Verheyen K. 2007. Long-term dynamics in a planted conifer forest with spontaneous ingrowth of broad-leaved trees. *Appl. Veg. Sci.* 10: 219–228.

Götmark F. 2007. Careful partial harvesting in conservation stands and retention of large oaks favour oak regeneration. *Biol. Conserv.* 140: 349–358.

Götmark F. 2013. Habitat management alternatives for conservation forests in the temperate zone: Review, synthesis, and implications. *For. Ecol. Manage.* 306: 292–307.

Götmark F., Paltto H., Nordén B., Götmark E. 2005. Evaluating partial cutting in broadleaved temperate forest under strong experimental control: Short-term effects on herbaceous plants. *For. Ecol. Manage.* 214: 124–141.

Grime J.P. 1977. Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. *Am. Nat.* 111: 1169–1194.

Halme P., Allen K.A., Auniņš A., Bradshaw R.H., Brūmelis G., Čada V., Clear J.L., Eriksson A.-M., Hannon G., Hyvärinen E. 2013. Challenges of ecological restoration: Lessons from forests in Northern Europe. *Biol. Conserv.* 167: 248–256.

Kint V., Lasch P., Lindner M., Muys B. 2009. Multipurpose conversion management of Scots pine towards mixed oak–birch stands—a long-term simulation approach. *For. Ecol. Manage.* 257: 199–214.

Kokarēviča I., Brūmelis G., Kasparinskis R., Rolava A., Nikodemus O., Grods J., Elferts D. 2015. Vegetation changes in boreo–nemoral forest stands depending on soil factors and past land use during an 80 year period of no human impact. *Can. J. For. Res.* 46: 376–386.

Kühn I., Durka W., Klotz S. 2004. Biolflor: A new plant-trait database as a tool for plant invasion ecology. *Divers. Distrib.* 10: 363–365.

Meilleur A., Veronneau H., Bouchard A. 1994. Shrub communities as inhibitors of plant succession in southern quebec. *Environ. Manage.* 18: 907–921.

Rendenieks Z., Brumelis G., Nikodemus O., Elferts D. 2019. Geographic determinants of spatial patterns of *Quercus robur* forest stands in Latvia: Biophysical conditions and past management. *iForest* 12: 349–356.

Roovers P., Baeten S., Hermy M. 2004. Plant species variation across path ecotones in a variety of common vegetation types. *Plant Ecol.* 170: 107–119.

Similä M., Junninen K. 2012. Ecological restoration and management in boreal forests–best practices from Finland. Metsähallitus Natural Heritage Services, Vantaa. 50 p.

Ulanova N.G. 2000. The effects of windthrow on forests at different spatial scales: A review. *For. Ecol. Manage.* 135: 155–167.

Vesterdal L., Raulund-Rasmussen K. 1998. Forest floor chemistry under seven tree species along a soil fertility gradient. *Can. J. For. Res.* 28: 1636–1647.

Widen M.J., O'Neil M.A.P., Dickinson Y.L., Webster C.R. 2018. Rubus persistence within silvicultural openings and its impact on regeneration: The influence of opening size and advance regeneration. *For. Ecol. Manage.* 427: 162–168.

Widerberg M.K., Ranius T., Drobyshev I., Nilsson U., Lindbladh M. 2018. Increased openness around retained oaks increases species richness of saproxylic beetles. *Biodivers. Conserv.* 21: 3035–3059.

Received 28 April 2020; received in revised form 11 May 2020; accepted 25 May 2020