RESTORATION OF BOG SPRUCE FORESTS IN THE GIANT MOUNTAINS, CZECH REPUBLIC

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Bog spruce forests are rare and endangered plant communities of central and western Europe. In the Czech Republic, they were intensively destroyed and drained before the change of political regime in 1989. To start the regeneration of bog spruce forests, palisade dams sealed with peat were used to block draining ditches in the Giant Mountains. Four years after dam construction, there were significant differences in vegetation of draining ditches above and below dams. These differences indicate that palisade dams effectively retain water and help the regeneration of the bog forest. Our results are necessary to support construction of palisade dams, and aid decision-making of the Krkonoše National Park Administration.

Introduction

Bog spruce forests are rare plant communities of central and Western Europe. In recent decades, they were intensively destroyed by human activity and their area decreased dramatically throughout Europe. This is why they are classified as a priority habitat, which is treated by directive 92/43/EHS (*1*). Drainage of bog spruce forests has a long tradition in the Giant (Krkonoše in Czech) Mountains. A first attempt to drain them comes from the 19th century. Paradoxically, the catastrophic flood of 1897 stopped this effort. Drainage of bog forests and deforestation of mountain belts were considered to be the main reasons of the catastrophe (*2*). In 1970 – 80's, they were destroyed by severe drainage and air pollution in the Giant Mountains (*3*). Drainage was performed despite the conservation status of Krkonoše National Park. In the Czech Republic, all types of wetlands were drained as part of existing government policy, which tried to increase agricultural and horticultural land production. Wetland drainage causes remineralisation, peat decomposition and leaching of minerals (*4*). These processes results in a decrease or disappearance of stress-sensitive species with weak competitive ability and small ecological amplitudes, and an invasion or increase of ubiquitous and nitrophilous strong competitors, often with wide ecological amplitudes.

In 1989, a change of political regime resulted in deintensification of agricultural and horticultural activities in less productive areas, and made possible the revitalization of mires, bogs and bog spruce forests.

Excavation of draining ditches caused in an increase in lateral seepage from the wetlands (*5*). Blocking these ditches is a necessary prerequisite to regenerate wetlands and requires insertion of a series of impermeable (or nearly so) barriers. Barriers (dams) raise water levels in the ditch. Damming stimulates regeneration of mosses and mire plants (*6*, *7*, *8*). Many successful attempts have been recorded from the insertion of plastic, plywood or palisade dams at regular distances to complete refilling of drains with peat (see *9*). To start regeneration of bog forests, palisade dams sealed up with peat were used to block draining ditches in the Giant Mountains. Palisade dams were used because of low cost and because they do not disturb landscape patterns. The aim of our study was to demonstrate the effectiveness of dam construction on development of vegetation of draining ditches. Monitoring the effectiveness is necessary for planning by the Krkonoše National Park Administration.

Methods

Nomenclature: for angiosperm plant species (*10*), for *Senecio hercynicus* (*11*) and for bryophytes (*12*).

Site description

The study site (Mrtvý vrch) is located 3 km north of the town Harrachov (50°48'15", 15°26'45", see Fig. 1). Altitude is 1058 m a. s. l. The mean annual temperature is 4°C and mean annual precipitation is 1400 mm (Harrachov and Szrenica meteorological stations). The Mrtvý vrch peat bog is a topogenic raised bog (*13*). According to the phytosociological nomenclature (*14*) the vegetation of the study site was classified as *Sphagno-Piceetum* (bog spruce forest) with some refuges of *Oxycocco-Empetrion hermaphroditi* (raised bog vegetation). *Avenella flexuosa* and *Calamagrostis villosa* were the dominant species, followed by *Molinia coerulea*, *Vaccinium myrtillus, Galium saxatile, Agrostis tenuis, Carex canescens, Eriophorum vaginatum* and other species. In early 1980', spruce trees (*Picea abies*) dominants died out because of air pollution and were removed. At the same time, draining ditches were excavated to lower the water table to increase stand productivity. The peat bog is situated in a slightly shallow depression of a granite pluton form. The bog surface is moderately south-face sloping. The maximum depth of peat accumulation is 2 m. A central drainage channel (ca 0.75 m deep) was dug out around the central peat bog. Two ditches were excavated to collect water from the central channel. To control water run-off and to stimulate regeneration of the peat bog, palisade dams were installed in channels in the summer of 1997. A total of 14 dams were installed, approximately 10 – 15 m distances apart from each other. Dams were sealed up by peat from the neighborhood (Fig. 4).

Data collection

In July 2001, 28 relevés was collected in the study area.

Vegetation cover was estimated visually using pairs of 1 m^2 plots established in draining channels. Each pair consists of plots on either side of a particular dam, and 1 m away. This experimental design is based on the presumption of the same vegetation in each pair of plots before the dams were established in 1997. At the location of a dam, the slope of the draining channel was recorded by a geological compass. The actual water table was measured as height of water-column above and below the dam at the time of vegetation data collection.

Data analysis

Redundancy analysis (RDA) in CANOCO program (*15*) was used to evaluate composition of plant species. Redundancy analysis is a direct gradient analysis method based on the assumption of a linear response, and was used because data sets were relatively homogeneous. RDA is also suitable for testing an effect of categorical environmental variables (position of a relevé). To evaluate the effect of position, the effects of slope and water table were removed from the model using both variables as covariables. A Monte Carlo permutation test (499 permutations) was used to test the significance of the model.

Permutations were performed within each pair of plots. The results of CANOCO analyses were displayed as ordination diagrams constructed by the CanoDraw 4.0 program.

Analysis of variance (ANOVA) was used to evaluate water table data.

Results

Four years after the dams were built, there was a significant difference in plant species composition revealed above and below dams (F = 2.604, P = 0.038, see table 1). This analysis explained 7.9 % of species data variability. *Sphagnum capillifolium, S. fallax* and *Dicranella cerviculata* were only present above dams. On the other hand *Brachythecium rutabulum, Calypogeia neesiana, Calystegia muelleriana, Dicranella heteromalla, Ditrichum cylindricum, Dryopteris carthusiana, Epilobium angustifolium, Luzula pilosa, Plagiothecium laetum* and *Tetraphis pellucida* were only present below dams. *Carex canescens* and *Eriophorum vaginatum* were more abundant above dams. *Avenella flexuosa, Calamagrostis villosa, Cerastium holosteoides, Dicranum scoparium, Galium saxatile, Juncus filiformis, J. squarrosus, Melampyrum pratense, Molinia coerulea, Polytrichum commune, P. formosum, Senecio hercynicus, Sphagnum russowii, Trientalis europaea* and *Vaccinium myrtillus* were more abundant below dams (Fig. 2).

At the time of relevés collection, there was no significant effect of dams on the water table (F = 4.05, P = 0.06) recorded. The mean water tables were 0.145±0.049 (max 0.71) and 0.045±0.009 (max 0.13) m above and below dams respectively. Non-significant results were caused by high variability among dams. Five dams were without any water. In one case, water table was higher below a dam (see Fig. 3 for details).

Discussion

Monitoring draining ditches cannot reveal all changes in bog hydrology and vegetation. This system was used for three reasons: simplicity, low time-consumption, and explicitness of obtained results. In the Krkonoše National Park, monitoring of revitalization treatments must follow these points, because results are used for practical decision-making and public relations. Experts of the National Park must be able to track a wide scale of monitoring events. Instead of basic research, our applied research must directly answer: yes – we will construct these types of dams or no – effectiveness is low, we must construct different type of dams or terminate their construction. If the changes in vegetation of all bogs are monitored, effectiveness of dams can hardly be revealed by reason of methodological difficulties, heterogeneity or long-term reaction of vegetation.

The more favorable hydrological conditions lead to a colonization of two *Sphagnum* species above dams. *Sphagnum* colonization depends on a source of diaspores and suitable environmental conditions for their establishment. In Price's study (*16*), the greatest water tension was observed in the blocked sites, rather than in drained sites, suggesting lower suitability of drained sites for *Sphagnum* canopy regeneration. Early colonists such as *Polytrichum formosum, Dicranella heteromalla* and *Dicranum scoparium* were overgrown by the marsh species above dams in our study. A rapid replacement of early succesional species by *Sphagnum* species was recorded after blocking a draining ditch (*8*). Rapid changes of vegetation were revealed in our study. A relatively slow increase of *Sphagnum* species four years after construction of dams can be a cause of severe summer droughts and by the relatively high slope of draining ditches. Although in 2001, there was an extremely rainy summer, five dams were without any water in the most sloped parts of draining ditches in July. This result indicates lower effectiveness of dams in the sloping terrain. Above dams, the coverage of dominant grasses was restricted. *Agrostis tenuis, Avenella flexuosa* and

Calamagrostis villosa lower coverage can be a reason of higher moisture content above dams for most parts of the year. Wet profiles retard temperature increases in spring and reduce the release of nutrients, oxygen supply, length of growing season and therefore the speed of peat mineralization (*17*). *Eriophorum vaginatum* and *Carex canescens* were only two vascular plants more abundant above dams. Both indicate differentiation of water conditions in relation to position. According to Grime (*18*) *Eriophorum vaginatum* behaves as an early colonist of bare peat after disturbance.

Rather xerophilous lichen *Cladonia pyxidata* occupied bare peat among the dwarf shrubs of both *Vaccinium* species near the water table above dams, in spite of findings that lichen grows only on the peat hummocks (*8*). A reasonable explanation of different results can be restricted to the competition of grasses and some mosses above dams in our study. The reason for drainage was the colonization by forest species that continued, in particular, below dams some time after damming. Prostrate herb *Galium saxatile* is moderately shade tolerant and can coexist with more robust species of higher competitive ability. Because it sometimes occurs in mire and aquatic habitats, its position below a dam was not surprising for us. *Vaccinium vitis-idaea* and *V. myrtillus* are long-lived and slower-growing shrubs of acid soils. Instead of *V. myrtillus,* leaves of *V. vitis-idaea* are evergreen – this adaptation enables them to maximize production per unit of limiting minerals in nutrient poor conditions. Therefore *V. vitis-idaea* is generally more abundant in peat bog than *V. myrtillus*. and was positioned above a dam. *Molinia caerulea* was more abundant below dams, because *M. caerulea* is a typical grass for bogs affected by severe summer droughts (*9*). It indicates more favorable conditions for mineralisation and mineral release, so *M. caerulea* is dominant species of drained peat bogs in the Czech Republic. *M. caerulea* is replaced by species such as *Juncus effusus* and *Eriophorum vaginatum* in waterlogged habitats, because *E. vaginatum* colonizes impoverished soils and appears to have more efficient mineral retention and recycling. *Juncus squarrosus* is a winter-green clump-forming rush, a species of moist soils. In our study, they were observed only below dams (except 1 occurrence). Probably, below the dams, there were gaps with an incomplete cover of vegetation, which *Juncus* usually prefers.

Spruce raised bogs are very specific and endangered habitats of the Czech Republic. They are characterized by specific site conditions and they are suitable for the survival of very specialized flora and fauna. As already stated above, drainage and removal of the original vegetation destroyed the functional relationships founded within an intact raised bog. Construction of dams for hydrological management of disturbed raised bogs is the simplest means for creating a large water-storage capacity. Blocking of drainage ditches seems to be fairly good for achieving spruce bog regeneration in the Giant Mountains. Our bog surface was moderately south-face sloping. We can conclude that building of smaller dams, but in shorter distances, is the most effectiveness means for water retention. To start bog forest regeneration, palisade dams sealed with peat seem to be a sufficient and inexpensive means for it and the construction of them will be continued in the Giant Mountains.

Acknowledgments

The research was supported by the Krkonoše National Park Administration. We are indebted to Tomáš Hájek and Steve Halperin for many valuable comments and to Jan Kučera for bryophytes identification.

Souhrn

Rašelinné a podmáčené smrčiny ve střední a západní Evropě patří mezi vzácnější rostlinná společenstva, jelikož byla ještě v nedávné době intenzívně disturbována exhaláty a především soustavným odvodňováním. V Krkonoších byla zahájena obnova tohoto ekosystému před čtyřmi roky budováním dřevěných přehrážek v odvodňovacích rýhách. Smyslem bylo zpomalit odtok vody z rašeliniště a tím nepřímo zvýšit hladinu spodní vody. Po provedeném zásahu jsme zjistili jasné rozdíly ve vegetačním složení nad a pod přehrážkou. Výsledky naší studie ukazují, že zvolený způsob obnovy je vhodný, a podporují tak další budování přehrážek.

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Došlo: 15.12.2002

Tab. 1: Results of the RDA analyses of cover estimates in 1m x 1m plots. Expl. var. = Explanatory variables, Covar. = Covariables, % ax 1 (all) = % species variability explained by axis 1 (all) – measure of the explanatory power of the explanatory variables, r ax 1 (all) = species environment correlation on axis 1 (all), F = F – ratio statistics for the test on the trace (all axes). P = corresponding probability value obtained by the Monte Carlo permutation test (499 permutations, i. e. Type I error probability in testing the hypothesis that the effect of one (all) explanatory variables is zero).

Anal.	Expl. Var.	Covar.	% ax 1 (all)	r ax 1 (all)	F 1 (all)	P 1 (all)
1	Above, Bellow	Water table, Slope	7.9	0.665	2.604	0.038
2	Slope	Above, Bellow, Water table	2.2	0.527	0.715	0.594
3	Water table	Above, Bellow, Slope	1.7	0.44	0.568	0.71
4	Above, Bellow, Slope, Water table		11.4	0.695	1.597	0.026

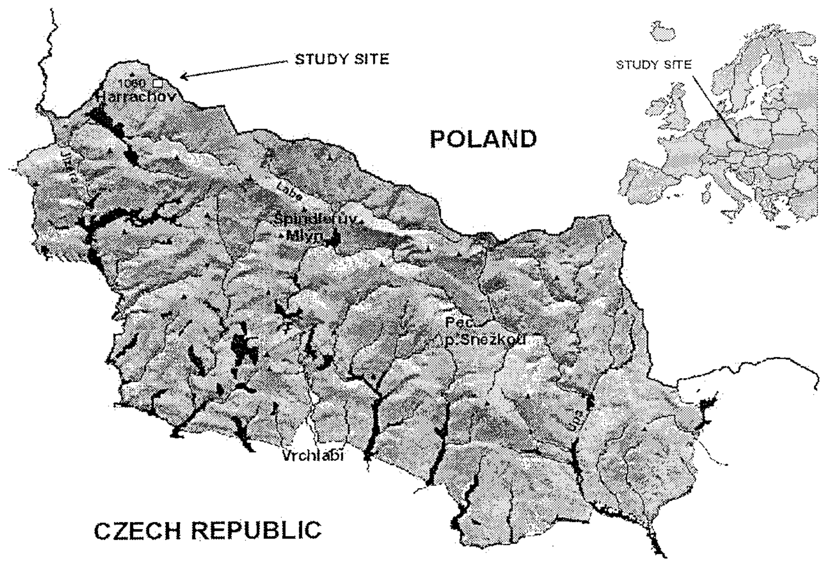

Fig. 1: Map of the experimental area. The Giant Mountains are located on the border of Czech Republic and Poland.

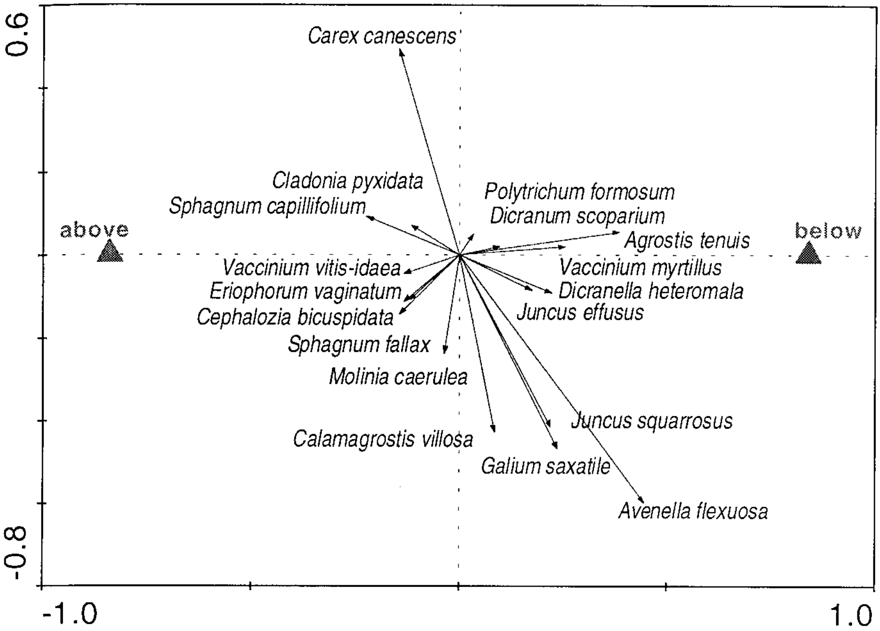

Fig. 2: Ordination diagram showing the results of RDA analysis where the position of reléves above and below dams was used as environmental variable.

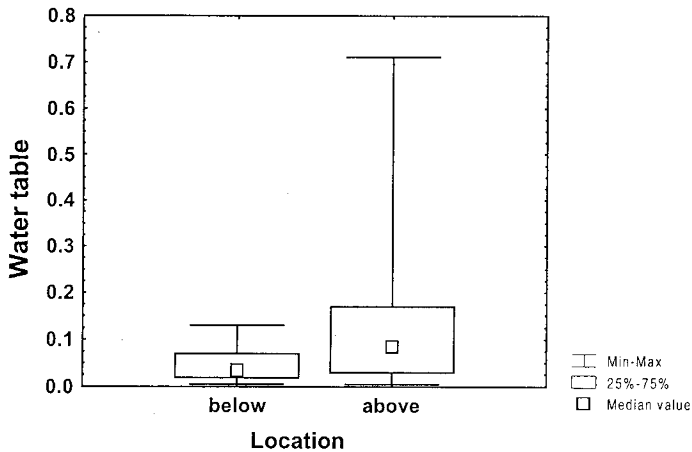

Fig. 3: Box and whisker plot of water table bellow and above dams.

Fig. 4: To start spruce bog forest regeneration, palisade dams sealed up by peat were used to block draining ditches in the Giant Mountains.