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Experimental restoration of coppice-with-standards: Response of understorey vegetation from the conservation perspective

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ABSTRACT

A substantial part of European lowland woodlands was managed as coppices or wood pastures for millennia. However, traditional management forms were almost completely abandoned in Central Europe by the middle of the 20th century. Combined with the effects of nitrogen deposition and herbivore pressure, shifts in management resulted in biodiversity loss affecting particularly light-demanding oligotrophic plant species. Experimental thinning was applied in a former oak coppice-with-standards in an attempt to restore vanishing understorey plant communities. Two levels of thinning intensity and zero management as control were used on 90 plots. Ten years after the treatment, significant changes in species composition and diversity were observed in heavily thinned plots, while moderate thinning had mostly insignificant effects. Light-demanding oligotrophic species significantly increased, indicating positive consequences of restoration. However, heavy thinning also brought about the expansion of native ruderal species. Alien species remained unchanged. We conclude that the restoration of coppice-with-standards can be an efficient tool to support vanishing light-demanding woodland species. Combined with biodiversity benefits, the increasing demand for biofuel may contribute to the renaissance of traditional management forms in forestry.

1. Introduction

A large part of European temperate lowland woodlands was historically managed as coppices or wood pastures (Bergmeier et al., 2010; Rackham, 2003). Retaining a certain density of standards (trees of generative origin) was a common feature in coppice woods, creating a structural and management type called coppice-with-standards. These woodlands were characterized by periodic harvests of coppice underwood removing substantial amounts of nutrients with the woody biomass. Frequent alternation of light and shady phases providing a patchwork of contrasting habitats was also typical for coppice woods (Ash and Barkham, 1976; Hölscher et al., 2001; Tybirk and Strandberg, 1999; Van Calster et al., 2008a). Such human impact has co-shaped European woodlands into specific ecosystems (Rackham, 2008).

In central and northwestern Europe, coppicing was almost completely abandoned by the 1940s due to changes in socio-economic conditions (Puettmann et al., 2008; Szabó, 2010). The extension of the cutting cycle resulted in prolonged periods of canopy closure, decreased light availability in the understorey and a consequent decline in biodiversity. The composition of vascular plants changed following various species traits (Naaf and Wulf, 2011) in favour of shade-tolerant and nutrient-demanding species at the expense of light-demanding oligotrophic species (Baeten et al., 2009; Hédl et al., 2010; Naaf and Wulf, 2011; Verheyen et al., 2012). A similar composition shift was observed in animal communities including invertebrates (Grundel et al., 1998; Spitzer et al., 2008; Verschuyl et al., 2011) and birds (Fuller and Henderson, 1992). Apart from the turn in woodland management from traditional methods to modern forestry, atmospheric deposition of nitrogen (Bobbink et al., 1998) and the increase in herbivore pressure (Chytrý and Danihelka, 1993; Hopkins and Kirby, 2007) have probably played important roles in the change from open-canopy, species-diverse forests to the present shady, nitrogen-saturated and species depleted forests.

It has been suggested that the biodiversity of coppices-with-standards can be restored and maintained by the re-introduction of traditional management (Barkham, 1992; Hermy et al., 1999; Kopecký et al., 2013). Particularly light-demanding species are expected to be supported by increased light availability in the understorey (Kopecký et al., 2013). There have been several

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successful restoration-motivated attempts to sustain declining invertebrate species (Broome et al., 2011; Buckley, 1992; Warren, 1987). However, fewer studies focused on the impact of coppice restoration on understorey plant species. A similar field experiment was conducted in Białowieża forest, where selective cutting of expanding hornbeam (*Carpinus betulus*) reversed a long-term trend and helped to restore an open-canopy oak forest community (Kwiatkowska and Wyszomirski, 1990).

However, the restoration of traditional management can also have adverse effects. Canopy opening increases soil surface temperature and therefore microbial activity (Concilio et al., 2005; Howson, 1988; Ryu et al., 2009), resulting in increased nutrient availability (Binkley, 1984; Inagaki et al., 2008; Vitousek and Melillo, 1979). This may stimulate the spread of nutrient-demanding, competitively strong species, some of which have alien and invasive species status (e.g., Radtke et al., 2013). This process threatens the conservation value of woodland vegetation. Soil disturbances caused by thinning operations may also promote ruderal species further devaluating the conservation value of affected woodlands (Battles et al., 2001; Decocq et al., 2004; Thomas et al., 1999).

To improve our knowledge about the outcomes of coppice-with-standards restoration, we conducted a restoration experiment in a central European lowland oakwood. Our aim was to describe how various thinning intensities change woodland structure and species composition on a gradient from a dry acidophilous oakwood to a mesic mixed oakwood. We particularly aimed at answering the question whether coppice-with-standards restoration is a viable way to restore vanishing plant communities. To emphasize conservation implications, we focused on light-demanding oligotrophic species, i.e. the group showing perhaps the most dramatic decline in European lowland forests. These species are not confined to woodlands, some also occur in open habitats, but not in ruderal sites. To assess the potentially negative effects of coppice-with-standards restoration, we also analysed the response of native ruderal and alien species.

2. Methods

2.1. Study site

The study site is Krumlov Wood in the southeastern part of the Czech Republic (16°22′N, 49°03′E). This region comprises a high proportion of light, oak-dominated woodlands hosting a variety of species. Shortly after the abandonment of coppice management, these woodlands harboured a high number of light-demanding oligotrophic species, including many recently endangered species (Hédl et al., 2010; Kopecký et al., 2013). The restoration potential of such sites, including Krumlov Wood, appears to be high. Krumlov Wood (35 km^2) is composed mainly of oak and oak-hornbeam communities. They range from acidophilous oakwoods dominated by sessile oak (*Quercus petraea* agg.) to mesic oakwoods with an admixture of lime (*Tilia cordata*), European hornbeam (*Carpinus betulus*) and pedunculate oak (*Quercus robur*). Altitude varies between 278 and 415 m a.s.l. Climatically the Wood belongs to a relatively warm and dry part of Central Europe, located near the northwestern fringe of the Pannonian Basin. The mean annual temperature and precipitation are 8–9 °C and 500–550 mm, respectively (Tolasz, 2007). The prevailing bedrock is biotitic granodiorite; calcareous sediments are locally present. The most common soil types are cambisols and luvisols. The first written record about the Krumlov Wood dates back to 1369. The Wood was mainly used as a source of firewood (Kyasová et al., 1970) partly as wood-pasture. Nowadays the Wood is composed mainly of trees of seed origin older than 110 years (former standards) and trees of vegetative origin (former coppices), 60–90 years old (Utinek, 2004a).

2.2. Experimental design

The field experiment was established in 1999 in the abandoned coppice-with-standards converted into high forest. We examined how the restoration of the active coppice-with-standards management influences the radial increment of remaining oak individuals, i.e. "standards" in the coppice-with-standards management system (Utinek, 2004a). The experimental design includes 90 plots divided into six ecologically distinct localities. In each locality, 15 plots with two levels of thinning intensity and 15 control plots with no thinning intervention were established using the counterbalanced measures design (Fig. 1; Utinek, 2004a, 2004b). Control plots were regarded to represent the initial conditions. Each locality contains five replicates of each treatment. The experimental design is therefore a two-factorial one, with the factors "locality" and "thinning intensity". Because of the lack of data documenting the pre-treatment vegetation, treatment effects were assessed by the differences between treatment and control plots.

The plots are circles of 10 m radius. A special type of tree thinning was applied once at the beginning of the experiment. The goal was to simulate the tree structure characteristic for coppice-with-standards (Troup, 1924). Economically viable mature trees (mainly oaks) were retained, whereas other individuals of different species were harvested (Fig. A.1); hornbeam and lime were completely eliminated from the heavily thinned plots where present. The average number of trees (DBH > 4 cm) before felling was 830 ha^{-1} with a basal area of 28.6 m^2 ha^{-1} (Utinek, 2004a). Mean tree density was reduced on average by 25% to 519 individuals ha^{-1} during the moderate thinning treatment and by 70% to 141 individuals ha^{-1} during the heavy thinning treatment. Similarly, basal area was reduced on average by 34% to 21.3 m^2 ha^{-1} after moderate thinning and by 83% to 8.5 m^2 ha^{-1} after heavy thinning.

2.3. Data collection

To capture the intensity of thinning, tree diameter at breast height (DBH > 4 cm) was measured in the circular plots using a girthing tape before thinning in 1999 and after thinning in 2001. Vegetation composition was sampled during the summer of 2009 in 10 × 10 m plots placed in the centers of the circular plots (Fig. 1). All vascular plants in the understorey layer (below 3 m of height) were recorded. Nomenclature follows Kubát et al. (2002). Percentage cover of the herb layer (0–0.5 m) and the cover-abundance of each species were visually estimated on a 9° Braun-Blanquet scale (Dengler et al., 2008). For data analyses, these values were

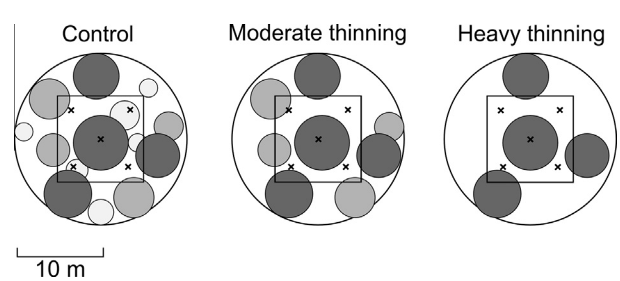

Fig. 1. Schemes of the three thinning treatments. Left: control (no intervention); center: moderate thinning (the smallest trees removed); right: heavy thinning (most trees removed, a few big trees retained). Grey circles represent individual trees. The outer circle delimits the extent of the thinned plot (10 m radius); the inset square shows the position of the vegetation sample plot (10 × 10 m). Crosses indicate locations where soil samples and hemispherical photographs were taken.