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Short communication

Removal of European alder *Alnus glutinosa*—An active method of mire conservation

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A B S T R A C T

Tree-less peatland communities can subject to vegetative succession, which often progresses toward a recovery of woodland or forest dominated by *Salix*, *Betula* or *Alnus glutinosa*. Since this process provides a threat to already established combinations of species and habitats of nature conservation value, there is a need to elaborate an efficient and environmentally friendly method of managing invading species. We investigated the effectiveness of removing invading black alder, *Alnus glutinosa* (~18 years old; up to 4 m tall), from a non-forest mire by applying a single cut. We tested whether alder removal was positively related to the height of the cut and the season of the year. Most mortality occurred in the first year after the cut. Three years later, the response to cutting showed a moderate increase in dead trees, especially among trees that had been cut in autumn. Stump height significantly affected tree mortality. A cut at breast height eliminated 22% of the trees, a cut 5–10 cm above the ground at the base of the trunk eliminated 36%, and a cut at or just below the ground surface eliminated 100%. The success of this *Alnus* elimination method is likely to depend on a combination of mechanical treatment and shallow inundation. Otherwise, *Alnus* removal will require additional measures, including herbicide treatment.

1. Introduction

Wetland ecosystems are controlled by various disturbances, such as fire, storms, flooding, grazing and logging (Keddy 2010). Disturbances, either natural or artificial, can convert an ecosystem to an alternative stable state or a dynamic state with different ecological structures and functions. In Europe, one common stressor is agricultural use, which in some places has continued for centuries. Extensive farming, including grazing and mowing together with the regular removal of biomass at a low or intermediate level of disturbance (Berglund et al., 2008), has contributed to the development of open ecosystems with specific combinations of plants and animals, often rare, that are protected by law (Craft, 2016; Natlandsmyr and Hjelle 2016).

In the absence of disturbances, wetland communities can be subject to vegetative succession that varies based on local and regional conditions (Gray et al., 2013; Woziwoda and Kopeć 2014) but often progresses toward a recovery of woodland or forest dominated by *Salix*, *Betula* or *Alnus glutinosa* (Douda et al., 2009; Falińska 1991; Güsewell and Le Nédic 2004). Well preserved and entirely natural treeless peatlands, which can survive without application of active conservation measures are not unique, but their occurrence in temperate regions of Europe is rather seldom (e.g. Wassen et al., 2006; Jabłońska et al., 2011; Pawlikowski et al., 2013). They survived in locations, where the abundance of water is maintained by a subsurface geology, as well as geomorphological and landscape settings (Banaszuk and Kamocki 2008; Jabłońska et al., 2014).

Black alder, *A. glutinosa* (L.), is a common water-demanding species that is widespread across all of Europe (Kajba and Gračan 2003). In northern Europe, *Alnus* makes up ~5% of the forest stands (Glavac 1972; Claessens et al., 2010), especially in waterlogged marshy and riparian sites, where it contributes to biological diversity by providing habitats for specific flora and fauna (Dussart 1999). Some of these sites (e.g., Fennoscandian deciduous swamp woods) are high-priority habitat types in danger of disappearance whose natural range falls mainly within the territory of the European Union (Council Directive, 1992; Interpretation Manual of European Union Habitats, 2013).

However, in invading treeless peatlands and riparian wet meadows after agricultural abandonment, *Alnus* may become a threat to already established combinations of species and habitats with acknowledged conservation value (Natlandsmyr and Hjelle 2016) by enhancing evapotranspiration (Eschenbach and Kappen 1999; Singh and Thompson 1995; Grygoruk et al., 2014) or eutrophication due to nitrogen enrichment (Bond et al., 1954; Mander et al., 2008; Vogel et al., 1997).

The spread of *A. glutinosa* is a serious problem in North America,

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where the species was probably first introduced in the late 19th century, and in Australia. Due to its easy adaptation to different environments and high reproductive potential, black alder became an oppressive invasive species (Anderson 2013; CABI, 2017).

Browsing by herbivores cannot prevent an invasion, as the animals tend to avoid eating the stems or bark because of their high tannin content (Gonzalez-Hernandezi et al., 2003). Also, use of controlled fire to eliminate *A. incana* was found rather ineffective (Brisson et al., 2006). Thus, the only efficient control method for adult European black alder is cutting. Cutting together with herbicide treatment is advised to prevent re-sprouting (Brisson et al., 2006). After cutting without further treatment, the *Alnus* stumps will produce multiple stems with dense branches that out-compete native species, blocking them from access to sunlight, water, and nutrients (Anderson 2013).

The use of pesticides may produce unknown cumulative impacts on the environment (Sura et al., 2012); therefore, their application in the EU is minimized or prohibited in protected areas, as defined in Directive 2000/60/EC, and in areas identified for the purposes of establishing conservation measures (Directive 2009/128/EC). In fact, their use is not allowed in protected areas in many countries in Europe, including Poland.

Presently, repetitive mowing and tree or shrub cutting are recognized as the only acceptable and potentially successful tools for succession control (Middleton et al., 2006; Kołos and Banaszuk 2013). Treatments that must be repeated every year have serious drawbacks, which include high costs and the possibility of enhanced environmental stress or disturbances caused by operating machinery (Banaszuk et al., 2016). Therefore, there is a need to establish baselines for the conservation of open ecosystems and to elaborate an effective, environmentally friendly and time-efficient method of managing *Alnus*.

The aim of this study was to assess the effectiveness of removing invasive black alder, *A. glutinosa*, in woodless peatland by applying a single cut. The principal issues pertained to the effect of both the method and timing of cutting on the sprouting ability and survival of black alder stumps. This study addressed the following questions: (i) Does applying a single cut without additional chemical treatment eliminate young black alder trees? (ii) How do cutting season and stump height affect the sprouting ability of *Alnus*?

2. Materials and methods

2.1. Study site

The Łosiniany peatland is a percolation mire with an area of 4 ha located on the slope of the Świsłocz River Valley (NE Poland, N53.187680, E23.865534; Fig. 1).

Peatland has developed on a large water outcrop that is evenly distributed over the year. The main peat body consists of a well-decomposed dark-colored peat whose depth may reach > 3.5 m. The lower peat layers sometimes contain carbonates and iron ore that have precipitated from the groundwater. The upper 20 cm of peat is slightly decomposed and has higher hydraulic conductivity, which enables near-surface water flow along a height gradient. On the east and lowest side, the peatland is naturally limited by the river. This kind of “live” peatland with well-preserved hydrology and vegetation is exceedingly rare in the Polish lowlands.

The vegetation is typically dominated by graminoids and forbs, with a well-developed bryophytes cover and occasional shrubs and woodlands of *A. glutinosa*. The Łosiniany peatland harbors a large number of the EU’s and the state’s rare plant species, e.g., *Liparis loeselii*, *Ostericum palustre*, *Dianthus superbus*, *Epipactis palustris*, *Dactylorhiza incarnata*, and *Swertia perennis ssp. perennis*. The population of the latter subspecies is the last and best-preserved on the country scale (Pawlikowski and Wołkowycki, 2010). Up to the second half of the 20th century, peatland was grazed by cattle and mown for fodder. The cessation of agricultural use triggered an encroachment of woody plants and shrubs, which in places started to dominate over an open wetland.

A part of the peatland (~3.2 ha) was drained by a combination of closely spaced (~1.2 m) plow furrows and afforested with *A. glutinosa* ~16 years ago. The trees were planted in furrows, which stretched across a slope following its elevation contour lines. The seedlings were spaced ~1 m apart.

NE Poland has a temperate climate with a mean air temperature of 7.0 °C. The monthly average temperature ranges from −3.9 °C in January to 17.8 °C in July, and the average rainfall amounts to 585 mm yr^{-1} (1951–2015), of which 60–80% falls between April and September. Permanent snow cover occurs over 70–80 days on average every year between late December and early March. The maximum snow depth reaches up to 80 cm in some years; however, in recent decades, warmer temperatures resulted in less winter snowfall and a significant drop in the snow-cover depth. The growing season starts at the beginning of April and lasts 180–200 days.

The period 2009–2015 experienced very high precipitation. The wettest year was 2010, when the sum of the rainfall amounted to 851 mm, and the sum of precipitation for the growing season exceeded 560 mm.

During the study period, for most of the year, the groundwater level oscillated at approximately 5 cm below the terrain surface (water level was measured using D-Diver data logger by Eijkelkamp Agrisearch Equipment, Giesbeek, the Netherlands, in a piezometer close to the experimental plots). Shallow (up to +3 cm) and short-lived (up to few days) inundations occurred occasionally during snowmelt. A prolonged drought in the summertime could result in a decrease in the water level as deep as −30 cm.

The shallow pore water from the depth of the root zone (0–10 cm; sampled by the Eijkelkamp Agrisearch Equipment vacuum sampler, Giesbeek, the Netherlands) of the mire was neutral at a mean pH of 7.8 ± 0.08 (n = 5; value in brackets is the standard error of mean; measurements represent the middle of the growing season) and exhibited a moderate electrical conductivity of 353 ± 19.0 μS cm^{-1} (Hach Lange HQ40D). The groundwater of the mesotrophic peatland was rather low in $N\text{-}NO_3$ at concentrations of 0.35 ± 0.06 $mg{\cdot}L^{-1}$, whereas the concentration of $N\text{-}NH_4^+$ was 0.57 ± 0.07 $mg{\cdot}L^{-1}$, and $P\text{-}PO_4^{3-}$ was 0.03 ± 0.01 $mg{\cdot}L^{-1}$. Relatively high concentrations of Ca^{2+} (63.3 ± 2.4 $mg{\cdot}L^{-1}$) and Mg^{2+} (23.0 ± 0.7 $mg{\cdot}L^{-1}$) confirm that the water feeding the wetland has a groundwater origin. The redox potential (Eh) of the solution was 138.0 ± 2.9 mV. The pore water sampled from a depth of 30–40 cm was anoxic, with the significantly lower Eh amounting to −80.3 ± 10.8 mV (P-value of the Kruskal-Wallis [K-W] test < 0.05), and was less abundant in $N\text{-}NO_3^-$ 0.12 ± 0.03 ($p < 0.05$), $N\text{-}NH_4^+$ − 0.39 ± 0.09 $mg{\cdot}L^{-1}$, and $P\text{-}PO_4^{3-}$ − 0.01 ± 0.01 $mg{\cdot}L^{-1}$.

2.2. Experiment

Within the forested peatland patch with even-aged (~18 years; up to 4 m tall) stands of *Alnus*, we randomly selected 6 plots (10 m × 10 m). The tree cutting was performed in two different periods of the year: at the end of the growing season in the middle of October 2011 (Autumn [A]) and in February 2012 (Winter [W]). Three methods were used: cutting at 0 cm or slightly below the ground (peat) surface (G); cutting 5–10 cm above the ground at the base of the trunk (B); and cutting the trunks at breast height, or 120 cm (H). Thus, we obtained six different treatment combinations: AG, AB, AH, WG, WB and WH. We randomly assigned the treatment type that each plot was to receive. Before the treatment, the diameter of the tree trunks was measured at breast height. The measurements were noted on a plastic plate, which was then stuck into the peat near the trunk. All the trunks and branches were removed from the site. We did not test the success of *Alnus* removal during the spring and summer to avoid disturbance of nesting or breeding birds.

After applying the treatment independently to each plot, we made