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Restoration of reindeer lichen pastures after forest fire in northern Sweden: Seven years of results

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ABSTRACT

Fire suppression since the 19th century has modified the functioning of boreal forest ecosystems in northern Sweden. In the long run, it induces changes in understory vegetation that result, especially on mesic sites, in feather mosses and Ericaceous dwarf shrubs outcompeting ground lichens, thus decreasing winter pastures for reindeer husbandry. In 2008, a field experiment was established in which, two years after a large forest fire, reindeer lichen (*Cladonia* spp.) was transplanted across various plots. The general objective was to accelerate the recovery of lichen-rich reindeer pastures, and test the ability of lichen thalli to establish on burnt surfaces following different post-fire treatments (tree harvest and standing trees retained), in different transplantation seasons (summer and winter) and at different doses (0.45 L m^{-2} and 2.25 L m^{-2}). The abundance and level of occupancy of *viable* and *established* lichen fragments was determined in 0.25 m^2 quadrats in 2010, 2013 and 2015. There was a continuous increase in lichen establishment over time, and seven years after transplantation, established lichen occupied, on average, 55% and 83% of the 0.25 m^2 quadrats treated with the lower and higher doses, respectively. Nine years after fire, no lichen had colonized the control, i.e. the burnt surface outside the experimental area. At the site with standing trees retained, lichen had already formed a well-established mat with a significantly higher lichen occupancy and abundance than in the open, clear-cut sites, where lichen agglomerated in proto-mats. Lichen transplanted in late-summer exhibited higher abundance and occupancy than that transplanted in late-winter. On average, the difference in lichen occupancy and abundance between different doses after seven years was of lower magnitude than between the doses of lichen transplanted initially. The experiment reveals useful results for the restoration of reindeer pastures and for specifying fire management regimes adapted to both forestry and reindeer husbandry.

1. Introduction

In Fennoscandia, winter grazing grounds with abundant lichen cover in the boreal forest represent a critical resource for sustainable reindeer (*Rangifer tarandus tarandus*) husbandry mainly undertaken by indigenous Sami people (e.g. Heggberget et al., 2002). In Sweden, it was recently estimated that the area of lichen-rich forests has declined by 71% over the last 60 years (Sandström et al., 2016). The reasons for this decline might have several intertwined origins: climate change induced greening (Cornelissen et al., 2001), commercial forestry (Kivinen et al., 2010), intensive reindeer grazing (Akujärvi et al., 2014), and finally the reduction in burned forest area during the last 150 years due to fire suppression.

In northern Sweden, fire suppression started around the end of the 19th century as a result of prohibition of setting anthropogenic fires and, for the first time in history, efficient suppression of uncontrolled fire hazards to protect timber resources (Granström and Niklasson, 2008, see Östlund and Roturier, 2011 for a review of Tirén 1937). Although fire burns out reindeer lichen for several decades, today there is evidence that lichen-rich *Pinus sylvestris* forests in Fennoscandia originate from repeated fires. Historically the fire return interval in Swedish dry pine forests ranged between 20 and 100 years (Engelmark 1984; Zackrisson, 1977), a much higher frequency than today, when expected return intervals are now hundreds of years (Niklasson and Granstrom, 2000; Wallenius, 2011). In the prolonged absence of fire, altered below- and above-ground properties induce changes in understory vegetation that

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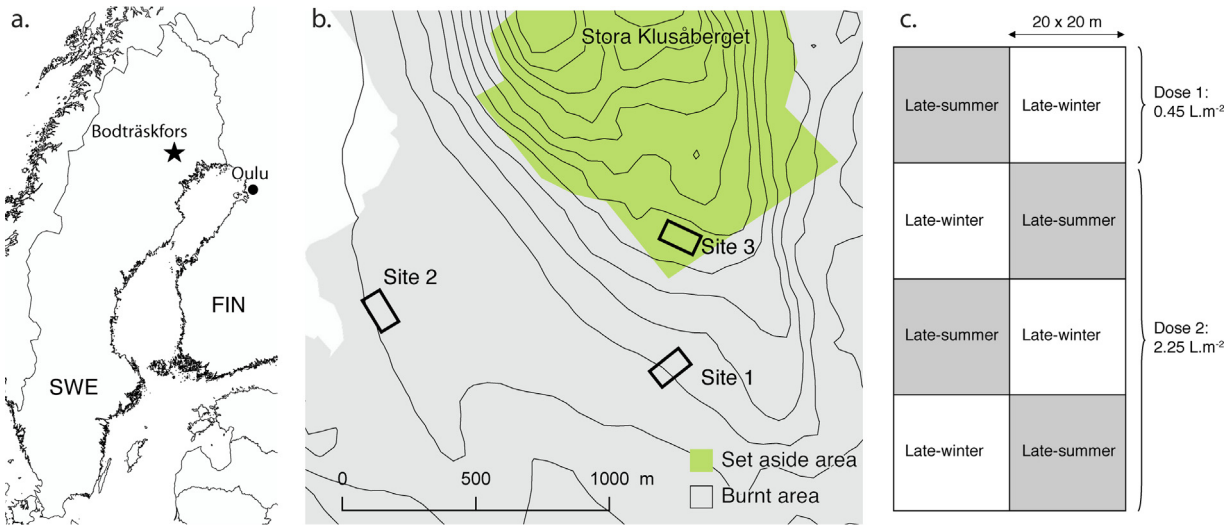

Fig. 1. (a) Location of the study area, (b) study area and (c) transplantation design at site level.

result, especially on mesic sites, in feather mosses and Ericaceous dwarf shrubs that can outcompete ground lichens (Nilsson and Wardle, 2005; Sulyma and Coxson, 2001).

The re-introduction of fire as a disturbance regime in Fennoscandian forests through restoration fire, prescribed burning prior to forest regeneration or wildfire, represents a straightforward option to ensure the restoration of suitable habitat for ground lichen in the long run, as it is for fire dependent species (Halme et al., 2013). However, the final successional phase in a plant community dominated by ground lichens is reached ca. 100 years after burning, mat-forming reindeer lichen species being dominant in the ultimate stages (Ahti and Oksanen, 1990; Morneau and Payette, 1989) depending on factors such as the fire severity or the distance from the dispersal source, even though burned areas may be used for reindeer foraging much earlier. In combination with fire, artificial dispersal of reindeer lichen could potentially contribute to much faster restoration and longer periods with lichen-rich pastures.

Reindeer lichens, a functional group including *Cladonia stellaris*, *C. arbuscula*, *C. rangiferina* and *C. uncialis*, mainly reproduce asexually and disperse by fragmentation of dry thalli, although there has been little quantification of the relative roles of sexual versus asexual propagation (Kotelko et al., 2008). Reproduction via fragmentation ensures that both symbionts are disseminated, but the colonization of the new habitats depends on the dispersal ability of the lichens (Esseen et al., 1981). For reindeer lichens, thallus fragments provide good short-distance dispersal but are inefficient for long-distance dispersal (Heinken, 1999). As a transplantation method, artificial dispersal of lichen fragments offers the advantage of creating multiple propagules from a material that is fairly easy to collect and manipulate. Transplanting entire mats would require much more material and would result in a much more destructive impact at the source of collection. Based on published (Roturier and Bergsten, 2009; Roturier et al., 2007) and unpublished results from field experiments, transplantation of fragmented reindeer lichen seems to be the most appropriate method.

The success of transplanting reindeer lichen fragments after fire is akin to inverting the post-fire chronosequence since propagules of reindeer lichens, traditionally considered to be late successional species, do not establish on newly burnt surfaces. This relates to the question of whether reindeer lichens are late successional species because they need a particular environment or substrate to establish and form a continuous mat, or because they are simply limited by their means of propagation, i.e. macroscopic propagules dispersed by wind and animals.

In this study, a field experiment was established in 2008 in which reindeer lichen fragments were artificially dispersed two years after a forest fire in boreal Sweden to investigate the restoration of reindeer lichen pastures. To our knowledge this was the first attempt to transplant reindeer lichen artificially in combination with fire at a large scale. The general hypothesis was that transplantation would significantly accelerate the recovery of the reindeer lichen mat on burnt forest soil. Our objective was to quantify the effects over time of transplantation season and amount (dose) of reindeer lichen in different stand environments produced by forest fire in order to accelerate the restoration of former lichen-rich ecosystems.

2. Material and methods

2.1. Study area

The study area is located in Bodträskfors, Northern Sweden (66°8′N, 20°50′E) (Fig. 1a). Since 2000 the mean annual temperature has been 1.1 °C. The mean annual precipitation is about 553 mm. On average, over a 20-years period, the annual snow cover has lasted between 175 and 200 days, usually forming in November and disappearing in May. The region is characterized by mid-north boreal vegetation with a tree layer dominated by Scots pine (*Pinus sylvestris*), with Norway spruce (*Picea abies*) occurring less frequently. The understory vegetation is mainly composed of Ericaceous dwarf-shrubs (*Vaccinium vitis-idaea*, *V. myrtillus*, *Calluna vulgaris*), feather mosses (*Pleurozium schreberi*, *Hylocomium splendens*) and lichens (*Cladonia* spp., *Cetraria* spp.).

In August 2006 a forest fire, accidentally caused in very dry conditions, burnt about 1900 ha over the southern slope of the hill Stora Klusåberget (273 m a.s.l.). Due to extremely dry conditions, the fire was very severe at some locations, consuming all the soil organic material and leaving mineral soil exposed. Following the fire, burnt trees were clear-cut except on the top of the hill where the forest was left untouched to become a set-aside area with standing dead and viable trees. In other areas, depending on the landowner, the stands have been planted with pine seedlings or have been allowed to regenerate naturally.

Before the fire, the study area consisted of tree stands of different ages. At the experimental sites the forest was dominated by Scots pine (75–150 years-old). The field-layer vegetation was classified as *Vaccinium vitis-idaea* type on sandy moraine soils, and the bottom layer was dominated by feather mosses.