



Addition of coarse woody debris – The early fungal succession on *Picea abies* logs in managed forests and reserves

Jörgen Olsson^{a,c,*}, Bengt Gunnar Jonsson^b, Joakim Hjältén^c, Lars Ericson^a

^a Department of Ecology and Environmental Science, Umeå University, SE-901 87 Umeå, Sweden

^b Department of Natural Sciences, Engineering and Mathematics, Mid Sweden University, SE-851 70 Sundsvall, Sweden

^c Department of Wildlife, Fish and Environmental Studies, SLU, SE-901 83 Umeå, Sweden

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ABSTRACT

Modern forestry practices have decreased the abundance of coarse woody debris (CWD), and as a result many species that depend on dead wood are now threatened. This implies a need to develop forestry practices that maintain biodiversity. We examined the conservation value of experimental spruce logs (control logs, logs placed in natural shade, and cut tree tops) for wood-inhabiting fungi in two forest stands, one nature reserve and one mature managed forest, in each of seven forest areas in northern Sweden. Here we report the initial findings of the experiment that was established in winter 2001–2002 and data were collected in 2002, 2003 and 2006. A pre-inventory of the local species composition in 2002 revealed a higher per area species richness, including red-listed species, in reserves than in managed forests. Ordination analyses of the experimental logs showed a significant effect of area, while not of stand type in 2003. ANOVA analysis showed no significant effect of stand type on species richness and abundance. In 2006, the species assemblage started to differentiate between the two stand types and forest age, forest site type (moisture), and distance to forest reserves, all explained part of the variation, whereas the amount of CWD, and species composition at the start of the experiment only showed a marginal effect.

The early successional fungal community was dominated by two functional groups, humus-decayers and white-rot species, both characterized by a rapid, early colonization and fruit-body formation on the competition-free new substrate. A similar positive response to the new substrate was also observed for the mycorrhizal species in 2006. The high frequency and early appearance of humus-decayers and mycorrhizal species that do not primarily depend upon CWD for their nutrition suggest that their formation of fruiting bodies is limited by substrate availability. Thus some mycorrhizal fungi are apparently rare due to lack of suitable substrate for fruit-body formation.

Evidence of dispersal-limitation was observed in 2006. *Fomitopsis pinicola*, an early colonizer in boreal forests, playing a key role for other wood-inhabiting organisms, colonized significantly more logs in the reserve stands compared with the managed stands. Our data demonstrate that lack of CWD strongly affects both species that depend upon wood for nutrition and species that depend upon wood for fruit-body formation. Thus some species may show an apparent rarity due to lack of suitable substrate. We conclude that creation of CWD appears to be a useful method to maintain or restore fungal diversity in boreal coniferous forests.

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1. Introduction

Intensive forest management has dramatically reduced the area of primeval forest in Fennoscandia and today the forest landscape is dominated by large areas of young, even aged coniferous monocultures (Axelsson and Östlund, 2001; Kouki et al., 2001).

Fragmentation of the remaining primeval forest together with lack of natural disturbance regimes has led to the situation that many species today are threatened and red-listed (Rassi et al., 2001; Gärdenfors, 2005; Kålås et al., 2006). Particular attention has been directed to decaying wood as it is of vital importance for a wide range of forest living organisms and forms an essential part of the forest ecosystem e.g. as substrate, and for structural heterogeneity, nutrient cycling and carbon dynamics (Harmon et al., 1986; Spies et al., 1988; Siitonen, 2001; Jonsson et al., 2005). The volume of coarse woody debris (CWD) has declined considerably in managed forests during the latest century (Linder and Östlund, 1998;

* Corresponding author at: Department of Ecology and Environmental Science, Umeå University, SE-901 87 Umeå, Sweden. Tel.: +46 90 786 86 56; fax: +46 90 786 81 62.

E-mail address: jorgen.olsson@vfm.slu.se (J. Olsson).

Sippola et al., 1998) and the average volume of dead wood (with a diameter ≥ 10 cm) in the middle and northern boreal Swedish managed forest is today about $6.5 \text{ m}^3 \text{ ha}^{-1}$ compared with an average around $80 \text{ m}^3 \text{ ha}^{-1}$ in natural forests (calculated from data in Fridman and Walheim, 2000; Siitonen, 2001). However, higher volumes of CWD ($>10 \text{ m}^3 \text{ ha}^{-1}$) may sometimes occur in over-mature managed stands, although with smaller variations in size, quality, and decay class distribution (Kruys et al., 1999; Jönsson and Jonsson, 2007; Josefsson et al., 2010). The loss of habitat and the decrease of dead wood have had negative effects on wood-inhabiting fungi (Lindgren, 2001; Siitonen et al., 2001; Penttilä et al., 2004; Laaksonen et al., 2008). In addition to declining populations, this also includes decreased genetic differentiation, reduced heterozygosity (Högborg and Stenlid, 1999; Franzén et al., 2007) and reduced spore vitality (Edman et al., 2004a).

Given the extensive fragmentation of the Fennoscandian forest landscape, the ability of long distance dispersal is of particular importance. For wood-inhabiting fungi dispersal-limitation has been documented over larger scales (Edman et al., 2004a, 2004b), while dispersal-limitation is generally considered not to occur at scales of <1 ha (Rolstad et al., 2004). However, large differences in spore deposition have been documented in landscapes with different intensities of forest management (Edman et al., 2004a, 2004b) and colonization may show spatial restriction within stands (Jönsson et al., 2008). Although it is logical to assume that spore deposition plays a critical role for a successful colonization, we still lack knowledge on the relationship between deposition load and a successful colonization event (Edman et al., 2004c). Further, at a more local scale, wood-inhabiting fungi may colonize dead wood by vegetative mycelial growth (Rayner and Boddy, 1988; Boddy, 1999). In addition to dispersal, fungal colonization depends upon a diverse array of other factors such as the physical and chemical properties of the substrate, the local microclimate and the actual species composition of the fungal community (Renvall, 1995; Niemelä et al., 1995; Boddy, 2000; Boddy and Heilmann, 2008). As a result wood-inhabiting fungal communities are highly dynamic.

Given the highly fragmented forest landscape, the question arises as to whether species are able to colonize available habitats. One important issue in conservation is that efforts should address the importance of larger spatial scales in contrast to the earlier focus on local stand characteristics (e.g. Edman et al., 2004a, 2004b; Hedenäs and Ericson, 2008). For instance, the new Swedish strategy for establishing protected area (Anon, 2005) explicitly identifies “ecological functionality” as one important criterion,

referring to the landscape context for the site considered for protection. To better understand the potential for different species groups to utilize available dead wood habitats, a large scale field experiment was set up in 2001 (Atlegrim et al., 2005). This experiment is based on a large number of experimental spruce logs that have been placed in a range of forest types representing different degrees of human influence. Previous publications have reported on colonization patterns of saproxylic insects (e.g. Hilszczański et al., 2005; Johansson et al., 2007; Hjältén et al., 2007), while the present study concerns wood-inhabiting fungi.

The aim of this study was to follow the first 4 years of the succession of wood-inhabiting fungi (mainly polypores and corticioids) on experimental spruce logs that had been placed in forest stands that differed with regard to habitat quality and past forest management. Specifically, we addressed the following questions; to what extent do the early stages of fungal colonization and succession vary in respect to (1) stand type (i.e. forest reserves and managed forests) (2) landscape context and (3) differences in log quality.

2. Methods

2.1. Study areas

The study areas are located within the middle and northern boreal zones (Ahti et al., 1968) in the counties of Västernorrland and Västerbotten, northern Sweden ($63^{\circ}4'N$ – $64^{\circ}2'N$ and $17^{\circ}0'E$ – $18^{\circ}5'E$). The dominant forest site types (following the classification of Arnborg, 1990) in the study areas are of mesic dwarf-shrub type and moist dwarf-shrub type, both with *Vaccinium myrtillus* L. as the dominant species in the field layer. A few stands belong to the dry dwarf-shrub type, with *Vaccinium vitis-idaea* L. as the dominant species in the field layer. Norway spruce (*Picea abies* (L.) Karst.) is dominant throughout most of the study areas, and to a variable extent mixed with Scots pine (*Pinus sylvestris* L.), birches (*Betula pendula* Roth and *Betula pubescens* Ehrh.), and more rarely Aspen (*Populus tremula* L.) and Goat willow (*Salix caprea* L.). The altitude of the study areas range from 220 m asl (Herrbergsliden) to 500 m asl (Rödberget).

2.2. Experimental design

Seven pairs of forest stands were selected within the two counties for the experiment (Fig. 1). The two stands in each area were

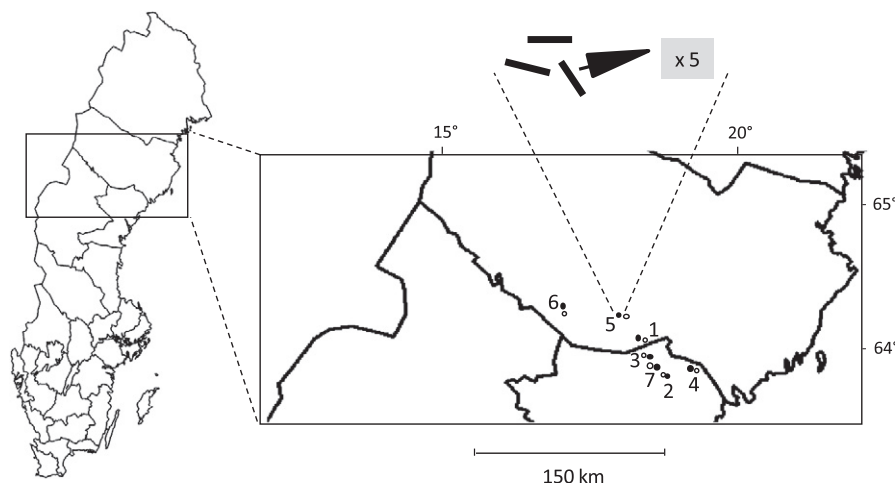


Fig. 1. Map of Sweden showing the location of the study areas (1–7) and the experimental design. Each area includes two forest stands, one called reserve stand (black circles) and one called managed stand (open circles). The experimental set up consists of five blocks with three cut logs and one tree top per area.

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