Forest Ecology and Management 371 (2016) 67–74

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Short-term effects of stump harvesting on millipedes and centipedes on coniferous tree stumps ☆

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ARTICLE INFO

Article history:
Received 15 October 2015
Received in revised form 17 March 2016
Accepted 17 March 2016
Available online 24 March 2016

Keywords:
Stump harvesting
Macroarthropods
Diplopoda
Chilopoda
Scandinavia
Forest biomass

ABSTRACT

In Sweden, tree stumps are currently considered as a potential resource for bioenergy production. However, environmental effects of stump harvesting – in particular when applied on a larger scale – are regarded as a potential threat to biodiversity in forests but are only poorly investigated. This is especially true for the numerous non-coleopteran macroarthropod groups inhabiting stumps. The aim of the present study was to investigate if a reduction in available dead wood due to stump harvesting in boreal coniferous forests has a negative effect on Diplopoda (millipedes) and Chilopoda (centipedes). We compared abundance, species richness and community composition (dominance patterns and similarity) of these groups on 3-year-old stumps remaining on stump-harvested (SH) clearcuts and non-harvested 'control' (C) clearcuts at 2 locations in central Sweden. For each investigated stump, animals were extracted from the total bark area (including the space between bark and wood), enumerated and determined to species level. Stump harvesting significantly decreased diplopod abundance per stump by 52% and changed community composition compared to clearcuts. Stump harvesting predominantly affected the abundance of two species (*Polyxenus lagurus* and *Proteroiulus fuscus*) that strongly dominated the diplopod communities on stumps. Mean species richness of diplopods on individual stumps was low (1–2 species depending on clearcut type and region) and was not affected by stump harvesting. Overall, eight diplopod species were found on stumps at both SH and C clearcuts. Only two species of chilopods were found on the stumps, occurring in low abundances and revealing no response to stump harvesting. The significant loss of diplopod specimens per stump after stump harvesting may be linked to a corresponding loss in function, particularly the mechanical breakdown of woody substrates. The results indicate that a reduction of habitats for stump species with low dispersal ability can both reduce their abundance per unit substrate and potentially also change the stump decomposition rate compared to sites with higher stump densities. Our results therefore highlight a need for careful consideration of increased intensity of stump harvesting at the landscape level.

1. Introduction

Increasing concern over climate change and limited supplies of fossil fuels have resulted in a growing need for renewable energy sources. In Sweden, tree stumps are currently discussed as a potential resource for bioenergy production. However, environmental impacts of stump harvesting – in particular when applied on a larger scale – are regarded as a potential threat to biodiversity in forests (Walmsley and Godbold, 2010). Stumps constitute a crucial habitat for many insect groups, particularly saproxylic beetles (Dahlberg and Stokland, 2004; Jonsell et al., 2004). In the Nordic countries, current stump harvesting practices remove between 50% and 80% of the stump volume on a clearcut (Eräjää et al., 2010; Rabinowitsch-Jokinen and Vanha-Majamaa, 2010; Victorsson and Jonsell, 2013a). This is a significant loss of habitat for saproxylic organisms and has been shown to negatively affect saproxylic insect communities (Victorsson and Jonsell, 2013b). For other invertebrate groups, information on possible effects of stump harvesting is lacking or scarce but equally urgent before stump harvesting is applied on a larger scale. One of the few studies investigating which macroarthropods prefer stumps over the soil habitat in clearcuts, concluded that millipedes (Myriapoda: Diplopoda) and centipedes (Myriapoda: Chilopoda) would probably decline in abundance on stump-harvested clearcuts (Persson et al., 2013). This seemed particularly true for millipedes which accounted for 29% of the macroarthropod abundance on the stumps.

☆ This article is part of a special issue entitled "Stump harvesting – impact on climate and environment".

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http://dx.doi.org/10.1016/j.foreco.2016.03.039
0378-1127/© 2016 Published by Elsevier B.V.

Detritivorous and fungivorous Diplopoda primarily function as primary or secondary decomposers of organic material and have a key role in the initial breakdown and comminution of organic matter (Wolters, 2000; Coleman et al., 2004). In stumps, they are important for decomposition *via* different mechanisms e.g. regulation of microbial catabolism rates and translocation of fungal spores/microbial cells into the stumps (Ausmus, 1977; Ulyshen and Wagner, 2013). Chilopoda on the other hand are higher-level predators that feed on a large range of invertebrates, in stumps their prey consists of e.g. larvae, earthworms and molluscs (Lewis, 2008). If stump harvesting negatively affects the abundance and diversity of these groups, then this could result in knock-on effects on terrestrial food webs and ecosystem processes such as decomposition of dead wood and related release of nutrients and therefore ultimately affect site productivity.

The majority of forests in Sweden are boreal coniferous forests that have relatively low abundances of Diplopoda, probably as a consequence of low pH and low-quality needle litter (Hopkin and Read, 1992). In these ecosystems, Diplopoda and Chilopoda commonly inhabit the forest floor, where they often live in the litter and uppermost humus layer (Jeffery et al., 2010). Their distribution is significantly influenced by the presence of dead and decaying wood with higher densities in closer proximity to coarse woody debris (CWD) (Evans et al., 2003; Jabin et al., 2004, 2007; Topp et al., 2006) which together with logs, stumps and living trees is also a favoured microhabitat (Berg et al., 2008; Golovatch and Kime, 2009). On forest clearcuts that lacked living trees, Persson et al. (2013) found 50% of the millipede communities on stumps even though stumps only accounted for 1% of the stand surface.

Clearcutting, which is a common silvicultural practice in boreal forests, is associated with a high degree of disturbance and it is likely that this impacts on Diplopoda and Chilopoda communities at a forest stand. Effects are expected to be further exacerbated by subsequent stump harvesting (Walmsley and Godbold, 2010). Around 70% of the surface soil layers in stump harvested clearcuts is disturbed (Kataja-aho et al., 2011), and soil compaction can be associated with heavy forest machines (Walmsley and Godbold, 2010). However, since stumps account for 75–80% of the CWD in clearcuts and young forest stands (Egnell et al., 2007), the most obvious, direct negative effect of stump harvesting on these animal communities would be the reduction in the amount of dead wood habitat.

The present study examines the impact of stump harvesting on Diplopoda and Chilopoda by comparing – in two Swedish landscapes – communities of both groups on stumps at ordinary 'control' clearcuts (C) where no stump harvesting had taken place with those at stump-harvested (SH) clearcuts. The latter had a 58% lower stump volume, which reflects present management guidelines for stump harvesting. We were exclusively interested in the direct effects of stump harvesting, i.e. a reduction in available dead wood. Our overall aim was to investigate if Diplopoda and Chilopoda communities on the stumps remaining in young clearcuts after stump harvesting differ from those on stumps at ordinarily managed clearcuts. We did not take into account possible effects of stump harvesting on litter or soil communities and sampled only diplopod and chilopod assemblages on stumps and not in the surrounding soil. Hence this sampling effort resulted in a selected number of species and is not representative of the whole Diplopoda and Chilopoda community on the clearcut. The study was conducted in relatively young clearcuts (3 or 3.5 years old) due to the lack of older (>5 years) stump harvest trials in Sweden. However, Diplopoda and Chilopoda are present on stumps at this early decomposition stage and do not differ significantly in abundance compared to communities on older stumps (10 and 20 years, Persson et al., 2013).

In our approach, we focused on the diplopod community because Diplopoda have been shown to reach much higher abundances on stumps compared to Chilopoda. We firstly quantified how many diplopods would be lost from stump-harvested clearcuts simply due to that stumps are extracted. It is important to assess the magnitude of a reduction in overall abundance at a clearcut, e.g. to formulate future guidelines for stump harvesting. Secondly, we determined if stump harvesting results in quantitative or qualitative changes in the Diplopoda assemblage on individual stumps, i.e. if stump harvesting leads to intrinsic changes in the stump communities. Our hypotheses were that stump harvesting (i) decreases diplopod abundance both at the level of the clearcut and also at the level of individual stumps and; (ii) decreases species richness and changes community composition of diplopods and chilopods on individual stumps.

2. Materials and methods

2.1. Study sites

The study was conducted in two regions in the boreo-nemoral (Lindesberg region, lat. 59°25′0″, long. 15°15′0″) and southern boreal (Finspång region, lat. 58°42′33″, long. 15°47′13″) vegetation zones of central and southern Sweden (Gustafsson and Ahlén, 1996). In these regions, approximately 70% of the land is covered by forest. Almost all forested land is intensively managed following standard Swedish practices, including clearcutting and thinning. The dominant tree species are Norway spruce (*Picea abies* (L.) Karst.) and Scots pine (*Pinus sylvestris* L.). Deciduous tree species, mainly birch (*Betula* spp.) but also European aspen (*Populus tremula* L.), alder (*Alnus* spp.), pedunculate oak (*Quercus robur* L.) and a few others occur as an admixture. A total of 15 clearcuts were selected that contained ⩾80% of Norway spruce stumps. The individual clearcuts had an average size of 7.3 ± 4.5 ha (mean ± SD). At the time of sampling, between September 2 and October 10, 2013, the clearcuts were 3–3.5 years old (time after final felling).

2.2. Sampling design

We sampled stumps in a blocked design where each block consisted of one stump-harvested (SH) and one non-harvested 'control' (C) clearcut except for one block in the Finspång region that consisted of two SH and one C clearcut. All clearcuts from that three-clearcut block in Finspång were included in the analyses since the statistical analysis performed (see Section 2.5) can accommodate this type of unbalanced data. We sampled four blocks in the Lindesberg region and three blocks in Finspång. Within blocks, clearcut size and time since final felling was similar and the same forest company was responsible for management. The inter-site distance between blocked clearcuts was between 339 m and 3780 m.

2.3. Sampling methodology

On each clearcut, eight *P. abies* stumps evenly spaced across the area were sampled. Stumps were selected by walking a set distance (50 m or 100 m, depending on clearcut size) along a selected compass bearing. Thereafter, the nearest *P. abies* stump (created at final felling) was sampled. Only stumps with a diameter of at least 16 cm and with at least 80% of the bark area remaining and with no visible damage from forestry machines were sampled. The majority of stumps were considerably larger than the minimum diameter and the sampled stumps had an average diameter of 36 ± 8 cm (mean ± SD) (range: 17–54 cm) and an average height of 35 ± 11 cm (range: 14–66 cm). From each sampled stump, all above-ground bark was collected – including loose debris between the bark and the outer sapwood – on sheets of white fabric spread