Journal of Environmental Management 198 (2017) 33–42

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Research article

Consequences of bioenergy wood extraction for landscape-level availability of habitat for dead wood-dependent organisms

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ARTICLE INFO

Article history:
Received 6 January 2017
Received in revised form
7 April 2017
Accepted 11 April 2017

Keywords:
Saproxylic
Cryptogam
Insect
Clearcutting
Habitat requirements

ABSTRACT

Stumps and slash resulting from forest clearcutting is used as a source of low-net-carbon energy, but there are concerns about the consequences of biofuel extraction on biodiversity. Logging residues constitute potentially important habitats, since a large part of forest biodiversity is dependent on dead wood. Here we used snapshot field data from a managed forest landscape (25 000 ha) to predict landscape scale population changes of dead wood dependent organisms after extraction of stumps and slash after clearcutting. We did this by estimating habitat availability for all observed dead wood-dependent beetles, macrofungi, and lichens (380 species) in the whole landscape. We found that 53% of species occurred in slash or stumps. For most species, population declines after moderate extraction (≤30%) were small (<10% decline) because they mainly occur on other dead wood types. However, some species were only recorded in slash and stumps. Red listed species were affected by slash and stump extraction (12 species), but less often than other species. Beetles and fungi were more affected by stump extraction, while lichens were more affected by slash extraction. For beetles and lichens, extraction of a combination of spruce, pine and birch resulted in larger negative effects than if only extracting spruce, while for fungi tree species had little effect. We conclude that extensive extraction decreases the amount of habitat to such extent that it may have negative consequences on species persistence at the landscape level. The negative consequences can be limited by extracting only slash, or only logging residues from spruce stands.

1. Introduction

The drive to find fuels that minimize human contribution to global warming is leading to consideration of new bioenergy sources. Forests managed for timber and pulp production provide a large potential source of low-net-carbon bioenergy, since large volumes of logging residues could be used (Parikka, 2004). In Finland and Sweden, the harvest of logging residues (slash and stumps) for bioenergy is already done to a great extent. However, the removal of logging residues will impact forest organisms through deterioration and loss of habitat (Bouget et al., 2012). Habitat loss has a large negative effect on biodiversity (Fahrig, 2003). Therefore, use of forest bioenergy could be in conflict with goals of biodiversity persistence (Walmsley and Godbold, 2010).

The largest effect on biodiversity observed is because the amount of dead wood decreases (Bouget et al., 2012). The amount of dead standing trees and downed logs has been reduced dramatically due to forest management. As a consequence, many dead wood-dependent species have declined and are on national red lists (Stokland et al., 2012). Logging residues have been found to harbour diverse species communities including beetles (Jonsell et al., 2007), fungi (Allmér et al., 2006), and lichens (Caruso et al., 2008), and dead wood-dependent organisms may thus be negatively affected by forest bioenergy extraction.

Extraction of logging residues has negative consequences for species richness of dead wood-dependent species at a local scale (e.g. fungi in areas within clearcuts: Toivanen et al., 2012; beetles per stump: Victorsson and Jonsell, 2013). However, removal of stumps and slash does not imply complete loss of habitat, since species using stumps and slash also use other dead wood types

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http://dx.doi.org/10.1016/j.jenvman.2017.04.039
0301-4797/

(Brin et al., 2013; Hämäläinen et al., 2015). Furthermore, some stumps and slash are left after harvest (Victorsson and Jonsell, 2013; Fritts et al., 2014), and stumps and logging residues are not harvested at all clearcuts. Therefore, landscape-level analyses considering the proportion of different dead wood types and organisms associated to them are needed to evaluate the impact of bioenergy wood extraction on forest biodiversity (Jonsell et al., 2007). However, only one such study considered all dead wood types, including fine woody debris (on lichens: Svensson et al., 2016). No previous studies have investigated how different levels of slash and stump extraction may affect future habitat availability or the effect of extracting different tree species.

The aim of this study was to investigate how populations of dead wood-dependent beetles, macrofungi, and lichens would change as a direct result of reduced habitat amount if stumps and slash on clearcuts were to be extracted. We used field data on dead wood, and species-specific data on beetle individuals, lichen coverage, and fungi occurrences from a 25,000 ha managed forest landscape. The specific questions we address are: (1) To what extent are different taxa utilizing stumps and slash from final harvest considering landscape levels of both logging residue wood and natural dead wood? (2) How might landscape-level populations of dead wood-dependent species be reduced by different levels of stump and slash extraction after clearcutting? (3) How will extraction comprising different tree species affect populations?

2. Methods

To investigate the effects of bioenergy extraction on landscape-level habitat amount and populations of dead wood-dependent organisms, we collected field data with methods making it possible to associate each observed specimen with a certain dead wood object where it likely has developed. Data on dead wood, and species-specific data on beetle individuals, lichen coverage and fungi occurrences on individual dead wood objects were used to (1) calculate the landscape-level amount of all major dead wood types, which here are stumps, fine woody debris (FWD), logs and snags (while dead branches on living trees were excluded) of dominating tree species in all types of productive forests (i.e. with a potential annual forest growth >1 m^3/ha) and (2) combine this with organism densities in each dead wood type in order to estimate landscape-level habitat-specific populations. Based on this, we compare a scenario with no bioenergy extraction in the landscape with scenarios with different types of bioenergy wood extraction where we estimate the proportion of populations that disappear according to the analysed scenarios.

2.1. Study landscape

All data were collected from a 24 449 ha landscape in the province of Hälsingland in central Sweden (62°N, 16°E). The studied landscape comprised a single block of land owned by one forest company, Holmen Skog AB (Fig. A1). Of the total landscape area, 20 294 ha were productive forest land and the remaining parts mainly mires and lakes. The landscape and tree species composition is typical of the central boreal region (Ahti et al., 1968), Since the 1950's, the forest has been managed more intensively and harvested by thinning and by clearcutting. The landscape is today mainly composed of even-aged stands. Stands older than 60 years are remnants of the forest before clearcutting, though they are heavily affected by single tree harvest (historical high-grading) and thinnings, while younger stands harbor one generation of trees growing after the last clearcutting. The least managed parts are found in three large, legally protected nature reserves, and some additional smaller voluntarily set asides (the latter according to the FSC certification standard) that together make up 13% of the forested area.

2.2. Data collection

Field data were collected between 2001 and 2014 with the view of being comparable to each other. We included all types of productive forests, and stratified the sampling based on a classification of stands into four categories: “Clearcuts” which are stands 3–14 years old, “Young forest” are stands 15–59 years old, “Old forest” are managed forest stands ≥60 years old and “Unmanaged forest”, which are voluntary set-asides and nature reserves. These four forest types cover approximately 2400, 9500, 5400, and 2700 ha respectively.

In 2001–2003, data on dead wood >10 cm in diameter (except stumps) and dead wood inhabiting beetles were collected (Ekbom et al., 2006; McGeoch et al., 2007). Additional data on dead wood amounts were collected in 2009 and 2014 for stumps, and in 2013-14 for FWD. Data on beetles were added in 2004 for high stumps, in 2009 for stumps (Jonsell and Schroeder, 2014) and in 2013 for FWD. Data on lichens and fungi in all types of wood were collected in 2013. The number of samples for each category varied (Table 1), as well as the number of investigated stands (Appendix A).

2.2.1. Dead wood surveys

Dead wood was surveyed by applying a stratified random sampling (Appendix A). The surveys for logs were done with four transects of 100 m (two east–west and two north–south) in each stand (Ekbom et al., 2006). By extending the same transects to 10 m on each side, 0.2 ha sampling plots for snags were obtained. Stumps and FWD were surveyed in 100 m^2 circular plots distributed in a regular quadratic network with 10–12 plots per stand (Jonsell and Schroeder, 2014). Data collected for each dead wood item is presented in Appendix B.

2.2.2. Calculations of dead wood amounts

For each stand, we estimated the amount of snags, stumps, and FWD per ha from plot estimates. The amount of logs was estimated by a line intersects method (Marshall et al., 2000). We used three different measures of dead wood considered to be the most suitable for beetles, lichens, and fungi, respectively: (1) surface area of bark covered dead wood, (2) surface area of bark free dead wood, and (3) dead wood volume.

Stumps were assumed to be habitat for 20 years after clearcutting (pers. obs.), but were not sampled in the Young forest category (15–20 years old). Therefore, we assumed that for a ninth of the area (= since 5 years is 1/9 of the age span for Young forest), the number of stumps was the same as on clearcuts, while in the remaining area they were as in field data.

2.2.3. Beetle survey

Beetles were surveyed under the bark of dead wood by sifting bark from wood objects sampled among those measured in the dead wood surveys (more details in Appendix C). The sifting was done in the field. In the lab, beetles were extracted from the resulting fine fraction using Tullgren funnels (Wikars et al., 2005). All sampling of beetles was conducted during the summer. A methodological comparison made in the study area revealed that the collected beetle species are changing over the year, with about twice as many species per sample at the peak during the spring compared to the summer (Wikars et al., 2005). Since we sampled all beetles in summer, our analyses are not biased, but the number of species observed to utilize different dead wood types would most likely have been higher if we had sampled at other seasons. Adults were identified to species and number of individuals per