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Dead wood availability in managed Swedish forests – Policy outcomes and implications for biodiversity

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ABSTRACT

Dead wood is a critical resource for forest biodiversity and widely used as an indicator for sustainable forest management. Based on data from the Swedish National Forest Inventory we provide baseline information and analyze trends in volume and distribution of dead wood in Swedish managed forests during 15 years. The data are based on ≈30,000 sample plots inventoried during three periods (1994–1998; 2003–2007 and 2008–2012). The forest policy has since 1994 emphasized the need to increase the amount of dead wood in Swedish forests. The average volume of dead wood in Sweden has increased by 25% (from 6.1 to 7.6 m^3 ha^{-1}) since the mid-1990s, but patterns differed among regions and tree species. The volume of conifer dead wood (mainly from *Picea abies*) has increased in the southern part of the country, but remained stable or decreased in the northern part. Heterogeneity of dead wood types was low in terms of species, diameter and decay classes, potentially negatively impacting on biodiversity. Overall, we found only minor effects of the current forest policy since most of the increase can be attributed to storm events creating a pulse of hard dead wood. Therefore, the implementation of established policy instruments (e.g. legislation and voluntary certification schemes) need to be revisited. In addition to the retention of dead trees during forestry operations, policy makers should consider calling for more large-scale targeted creation of dead trees and management methods with longer rotation cycles.

1. Introduction

Dead wood is the most important factor influencing forest biodiversity in boreal (Esseen et al., 1997), temperate (Paillet et al., 2010) and tropical forests (Grove, 2002). Around 7500 forest species in the Nordic countries are known to be dependent on dead trees during whole or part of their life cycles (Stokland et al., 2012), i.e. defined as being saproxylic (Speight, 1989; Stokland et al., 2012). This corresponds to 20–25% of all forest species (mainly fungi and invertebrates) in the region (Siitonen, 2001). As a consequence of modern forestry, the volume of dead wood has decreased significantly as pristine forests have been converted into managed stands. Throughout Europe, the current volumes of dead wood in managed forests are normally less than 10% of natural levels (Stokland et al., 2012). Along with the decrease in volume, the composition in terms of tree species, diameter distribution and decay classes has changed dramatically (Jönsson and Jonsson, 2007; Blaser et al., 2013). With significant habitat loss, it is not surprising that many saproxylic forest species are declining. For example, more than 700 species of the 2000 red-listed forest species in Sweden are dependent on dead wood (Larsson, 2011).

A significant amount of research is available on the strong dependence between the occurrence of saproxylic species and specific dead wood types (see reviews by Harmon et al., 1986; Jonsson et al., 2005; Stokland et al., 2012). This particularly concerns habitat specificity of species with regard to tree species, tree size, substrate type, and decay stage, with a superimposed role of the environmental conditions provided by the forest stand itself (Stokland et al., 2012). The Swedish Species Information Centre provides online data (http://artfakta.artdatabanken.se/, accessed in October 2015) on the requirements of red-listed species, showing the number of species dependent on different tree species. The data includes around 750 saproxylic red-listed species. Their habitat demands partly mirror the general abundance of the different

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tree species as a significant number of them are dependent on the dominant species (*Pinus sylvestris* L. and *Picea abies* (L.) Karst.). However, the data also highlights the importance of temperate deciduous tree species (see below), which have the highest number of associated red-listed species. Lack of dead wood from deciduous trees is one of the most important factors limiting biodiversity in the Swedish forest landscape. Attempts to estimate threshold levels for dead wood have been made. In a review of European forest ecosystems, Müller and Bütler (2010) conclude that the thresholds for occurrence of many saproxylic species are within the range of 20–50 m^3 of dead wood per hectare. Such estimates serve as a bench mark for evaluating existing volumes in managed forests and as management guidelines. However, these values only concern species frequent enough to allow statistical analysis of their occurrence. Relevant data allowing for analyses of the specific demands of rare species are largely lacking.

In 2011 the European Union (EU) established its Biodiversity Strategy, aiming to halt biodiversity loss by 2020. Among agreed targets and actions, Action 12 in the strategy relates to integrating biodiversity measures in forest management plans, and states that one measure is "to maintain optimal levels of dead wood" (Anon., 2011). The strategy does not define "optimal levels" in quantitative terms, but explicitly refers to the EU Species and Habitat Directive that calls for "Favorable Conservation Status" (FCS) for listed habitat types and species. This highlights the need for better baseline information on dead wood availability in different forest types and setting the current volumes in relation to the demands of saproxylic species (Travaglini et al., 2007).

Since the early 1990s Swedish forest management has begun to show greater environmental concern during its forestry operations (Simonsson et al., 2015). This is reflected in the Forestry Act from 1993, and also in the voluntary forest certification schemes (Angelstam et al., 2013; Johansson et al., 2013) that currently certifies a large portion of the Swedish forest landscape. Both the Forestry Act and the certification schemes highlight the importance of dead wood for forest biodiversity and the recommendations also include quantitative statements. For instance, the FSC standard requests, in addition to a general statement of retaining dead wood during forestry operations, that at least three high stumps or girdled trees per hectare should be created at final harvest, striving to include different tree species (Anon., 2014a). In addition to these sectorial policies, the Swedish government adopted a set of national environmental quality objectives in 1999 (Anon., 2001), including an objective of "Sustainable forests". This objective included increasing the volume of hard dead wood (<10% of the volume decayed) by at least 40% throughout the country and considerably more in areas where biological diversity is particularly at risk. In later revisions of the objectives, hard dead wood was also included as a critical indicator for sustainable forestry. Therefore, given the policy focus on dead wood during the past 15 years it is reasonable to expect that the volumes of dead wood should have increased in Sweden's forests.

Although it is well established that the volume of dead wood is generally low in managed forests (e.g. Stokland et al., 2012; Kebli et al., 2012), we have surprisingly little detailed information about the composition and structure of dead wood. Usually, at national level only crude averages over large regions and wood types are reported (but see Fridman and Walheim, 2000; Kruys et al., 2013). Although this does provide information on general habitat loss and current trends, it lacks the detail required to devise practical recommendations for managers to improve conditions for biodiversity. Critical questions such as, how much and what types of dead wood to protect and to potentially create (Jonsson et al., 2005) cannot be addressed based on current information.

Since the 1920s the Swedish National Forest Inventory (NFI) describes the state of and changes in Sweden's forests (Fridman et al., 2014). The information is used as a basis for forest and environmental policy and planning. On an annual basis around 7000 permanent plots are inventoried throughout the country, and include since 1994 detailed estimates of dead wood. Hence, large amounts of data on dead wood in Swedish forests is available from the last 15 years. Fridman and Walheim (2000) made an initial analysis based on data from 1994 to 1996 and found a national average of 6.1 m^3 ha^{-1}, but with significant geographical variation. In a recent study Kruys et al. (2013) analyzed structural changes in young forest stands (0–10 years old), including estimates of dead wood. They found a general increase of dead wood in young forests during the last 10 years, but similarly to Fridman and Walheim (2000) also large geographical variation. Besides these studies, the NFI annually reports total volumes in different counties for two decay classes (<10% or >10% of the wood volume decayed) and three groups of tree species (*P. sylvestris*, *P. abies* and deciduous trees). The current reporting scheme does not fully utilize the wealth of data available and there are strong reasons to extend the analyses made by Fridman and Walheim (2000) and Kruys et al. (2013) based on a longer time period and the significantly larger data set now available. The current analysis will provide forest and conservation management with a better understanding on the current dead wood resources and its impact on biodiversity in managed forests. The analysis will further emphasize the potential to use national forest monitoring to evaluate the effects of changed management guidelines.

This study aims to provide baseline data and estimates of trends in the availability of dead wood in Swedish forests and to evaluate the effects of the changes in forest policy related to dead wood since 1994. As such it represents a case on how ambitious conservation policies may or may not result in changes supporting forest biodiversity. The analyses are based on sample plot data from the NFI and will highlight variation in volumes with regard to

- Changes in dead wood volumes during a 15 year period in five regions.
- Dead wood volumes in different forest types according to habitat types defined within the European Species and Habitats Directive, i.e. the so called Natura 2000 habitats.
- Dead wood distribution among tree species, decay classes, and stem diameters within different regions.

2. Material and methods

2.1. Study area

Two thirds of Sweden are covered by forests (based on the FAO forest definition; FAO, 1998), mainly composed of boreal forests dominated by conifers. The area of the productive forest land (defined as producing more than 1 m^3 ha^{-1} per year) comprises 23.2 million hectares. This study is based on data from all managed, productive forests (excluding formally protected areas) in Sweden, except for the belt of mountain birch forests along the Scandes Mountains in the northwest part. The area of protected forests is unevenly distributed and only 3.6% of the productive forest land is formally protected (Anon., 2014b). This means that our analysis includes more than 96% of the productive forest.

Most of the study area has been subject to industrial forestry, starting on a larger scale in the southernmost part from the early 1800s and expanding northwards through the whole country during the 19th century (Östlund et al., 1997; Axelsson et al., 2002). The first wave of forest extraction targeted large diameter classes for saw timber and other purposes, which reduced growing stock (volume of live trees) significantly up to early 20th century. Forest management developed during this time period and the growing stock has increased with 104% since the 1920s (Anon., 2015). Clearcutting