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Relative contributions of set-asides and tree retention to the long-term availability of key forest biodiversity structures at the landscape scale

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ABSTRACT

Over previous decades new environmental measures have been implemented in forestry. In Fennoscandia, forest management practices were modified to set aside conservation areas and to retain trees at final felling. In this study we simulated the long-term effects of set-aside establishment and tree retention practices on the future availability of large trees and dead wood, two forest structures of documented importance to biodiversity conservation. Using a forest decision support system (Heureka), we projected the amounts of these structures over 200 years in two managed north Swedish landscapes, under management scenarios with and without set-asides and tree retention. In line with common best practice, we simulated set-asides covering 5% of the productive area with priority to older stands, as well as ~5% green-tree retention (solitary trees and forest patches) including high-stump creation at final felling. We found that only tree retention contributed to substantial increases in the future density of large (DBH ≥35 cm) deciduous trees, while both measures made significant contributions to the availability of large conifers. It took more than half a century to observe stronger increases in the densities of large deciduous trees as an effect of tree retention. The mean landscape-scale volumes of hard dead wood fluctuated widely, but the conservation measures yielded values which were, on average over the entire simulation period, about 2.5 times as high as for scenarios without these measures. While the density of large conifers increased with time in the landscape initially dominated by younger forest, best practice conservation measures did not avert a long-term decrease in large conifer density in the landscape initially comprised of more old forest. Our results highlight the needs to adopt a long temporal perspective and to consider initial landscape conditions when evaluating the large-scale effects of conservation measures on forest biodiversity.

1. Introduction

Habitat loss is considered a leading driver of biodiversity decline worldwide (Pimm and Raven, 2000; Brook et al., 2008). This is particularly evident in regions where native vegetation has been converted to divergent land cover types; for example where forests have been logged and replaced by crop and pasture lands (Foley et al., 2005). However, habitat loss may also take more subtle forms. In the boreal biome, which includes 27% of the world's forests (Hansen et al., 2010), the advance of industrial forest management has led to declines in a range of forest attributes directly relevant to the maintenance of biodiversity. Here, for many species,

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habitat loss has taken the form of a decrease in the area of forest containing sufficient amounts of key resources such as large trees, dead wood, and cavity-bearing trees (Angelstam et al., 2004). As a consequence, large numbers of boreal forest species have suffered population declines (Berg et al., 1994; Gustafsson and Perhans, 2010). Within Fennoscandia, for example, approximately 2000 forest-associated species are currently represented on each of the respective national red lists of Norway, Sweden and Finland (Larsson, 2011).

Society has responded to these negative environmental trends by developing a variety of governmental policies (McDermott et al., 2010) and market-driven conservation initiatives (Angelstam et al., 2013). In Fennoscandia, most policy tools specifically aiming to conserve forest biodiversity were developed and implemented fairly recently from a forestry perspective, mainly in the later parts of the 20th century (Angelstam et al., 2011). For example, the current Swedish Forestry Act, which stipulates the equal importance of production and environmental goals in the managed forest landscape, was adopted in 1993 (SFA, 2010). The 1990s also witnessed the establishment of international forest certification organizations such as the Forest Stewardship Council (FSC) and the Programme for Endorsement of Forest Certification (PEFC), which would take a leading role in the development of forest environmental policies.

The new environmental policies resulted in the implementation of novel conservation practices over the last ~20 years. Clearcut practices have been modified to retain trees, singly or in groups, dispersed over the harvested area. The aim of this approach, which is commonly applied in many parts of the world, is to provide for the long-term retention of key structures and small areas of intact forest throughout the rotation cycle (Gustafsson et al., 2012). At the same time as tree retention became common practice in the commercially managed forest matrix, the area of protected forest increased (Angelstam et al., 2011). In Sweden, productive forestland has been set aside through formal legal protection (e.g. 3.6% as nature reserves) and as voluntary set-asides (4.8%), i.e. forest areas protected for biodiversity conservation by the land owners without direct economic compensation (Elbakidze et al., 2011; Johansson et al., 2013a; SFA, 2013). Through those processes, large numbers of forest stands identified as woodland key habitats and other areas of high conservation value – often with old-growth characteristics – were set aside from commercial forestry operations (Gustafsson and Perhans, 2010). This trend is not unique to Fennoscandia; recent increases in the levels of tree retention and forest protection have also taken place in a large number of other forested countries worldwide (McDermott et al., 2010).

There is strong demand from society to evaluate the likely effects of implementing new conservation paradigms on future biodiversity in production forest landscapes (McDermott et al., 2010). However, as a consequence of the inherently slow rate at which forestry systems develop – especially at higher latitudes – the full landscape-scale effects of recently implemented biodiversity conservation approaches may take several decades or even centuries to materialize. Several empirical studies have assessed the short-term effects of retention practices on the availability of key structures for biodiversity (e.g. Hautala and Vanha-Majamaa, 2006; Kruys et al., 2013) and the extent to which these structures are used by forest organisms (Rosenvald and Lõhmus, 2008), but since retention practices were introduced rather recently it has been impossible to study long-term effects empirically. Similarly, the effects of setting aside forest for biodiversity conservation may involve long delivery times. Many set-asides have been adversely affected by commercial forestry in the past and currently possess limited amounts of structures of importance to biodiversity relative to historically unmanaged forest (Jönsson and Jonsson, 2007). Hence the capacity of set-asides to provide suitable forest habitats is expected to increase in the future, as key forest structures develop over time due to the allowance of more natural processes of growth, tree mortality, and decay (Ranius and Kindvall, 2004; Mazziotta et al., 2014).

The overarching aim of this study was to explore the long-term effects of recently adopted forest environmental policies on forest structures of special significance to biodiversity conservation. We performed the study in Sweden, a predominantly boreal country characterized by a long history of forest management. Sweden has slightly over 28 million ha of forest of which approximately 23 million ha is considered productive (i.e. annual forest growth ≥ 1 m^3 ha^{-1}). The remaining forestland is called ‘low-productive’ and nearly totally excluded from management due to legal restrictions. The majority of productive forestland has been actively managed for at least a century. Clearcut (i.e. clear-felling) forestry is the dominating silvicultural system, widely used in the country since the 1950s. This system is characterized by an even-aged stand structure that follows a cyclic harvest-and-regeneration pattern at the stand level. The rotation length is normally set to optimize average wood production and is in the range 60–120 years, depending on the region and site quality.

The specific aim of the study was to simulate and contrast the long-term effects of set-aside establishment and tree retention practices on the future availability of key structures for forest biodiversity. For this purpose, we used software to simulate future forest dynamics over two centuries, with and without set-asides and retention practices. We performed the study in two existing boreal forest landscapes having distinct initial age class distributions of forest stands. We assessed the implications for biodiversity by projecting the resultant availability through time of two forest structures of demonstrated importance to boreal forest biodiversity: large trees and dead wood. Large trees play critical roles in forest ecosystems due to their particular characteristics including a rough bark structure, large crowns, as well as frequent occurrence of cavities, sap flows and large-diameter dead branches (Nilsson et al., 2002; Lindenmayer et al., 2012). Dead wood is recognized as a crucial resource for a large number of species in boreal forests (about 20–25% of all forest species in Fennoscandia; Siitonen, 2001), including many threatened taxa (Berg et al., 1994; Rassi et al., 2010). We expected that both set-aside establishment and green tree retention would significantly increase the mean amounts of large trees and dead wood at a landscape level in comparison to a management regime without these practices, and that these effects would require many decades to materialize. Considering the low shade-tolerance of boreal deciduous trees and the prioritization rules currently implemented in practical forestry, we also hypothesized that the future abundance of large deciduous trees would mostly be influenced by retention at clear-felling, while large conifers would benefit significantly from the establishment of set-asides.

2. Material and methods

2.1. Overview of the approach

We projected the availability of large trees and dead wood in two managed forest landscapes over 200 years, starting in the early 1990s, i.e. just before the large-scale implementation of the new conservation practices. This was done by simulations of forest development, including dead wood dynamics, under four scenarios: one without the establishment of set-asides or tree retention at clear-felling, a second with set asides only, a third with tree retention only, and a fourth with both set-asides and tree retention. The choice of 200 years as a simulation horizon was based on our expectation that it may require more than one tree generation for