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Do conservation measures in forest work? A comparison of three area-based conservation tools for wood-living species in boreal forests

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ABSTRACT

Loss of natural forests and decline in forest biodiversity has led to several policy initiatives in recent years. Despite this, the importance of smaller set-asides vs forest reserves for conservation measures is poorly understood. We aimed to evaluate the importance of three different area-based conservation measures commonly used in north-European forests; retention patches, woodland key habitats and forest nature reserves. We did this for two contrasting ecological systems; *fungi in late-decay spruce logs* and *beetles in early-decay aspen snags*.

Eight replicated sites for each of the three conservation measures were investigated in a total of four boreal forest landscapes in south-Norway. Fungi were surveyed on existent late-decay spruce logs in two landscapes, and beetles trapped on experimentally added aspen dead-wood units in three landscapes. Richness and species composition were analyzed separately for specialist and generalist species.

We found larger differences in species composition between conservation measures for old-growth fungi specialists than generalists, although species richness patterns were less clear. The main contrast was found between nature reserves and retention patches. On the other hand, specialist beetles associated with early-decay aspen showed no difference between set-asides. The assemblage of aspen generalist beetles tended to be richest in the woodland key habitats and showed clear differences between the conservation measures. There was considerable variation in response to conservation measures between landscapes, related to quality of the set-asides.

Species specialized to an ephemeral, early-decay system were able to utilize such substrates in all of the conservation measures, while the smaller and more modified set-asides could not cater for the specialists dependent on stable, late-decay systems. Species with broader habitat demands in general responded to all conservation measures. We conclude that retention patches, woodland key habitats and forest reserves fill complementary functions for wood-living species in boreal forest and should all be part of future forest conservation strategies.

1. Introduction

An increasing concern surrounding the loss of natural forests and the decline in forest biodiversity has led to a rise in research and policy initiatives in recent years. One important initiative is the Strategic Plan for Biodiversity 2011–2020, drawn up by the Convention on Biological Diversity and agreed upon by the governments of the world in Japan 2011. It states that by 2020, at least 17% of the areas of particular importance for biodiversity and ecosystem services are to be conserved through "ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures". If we are to reach this target for the forest ecosystems of the world, we need a much better empirical understanding of the functioning and the relative importance of forest reserves and smaller set-asides than we have today.

1.1. Conservation measures in forestry

In the past 25 years, forest conservation measures have shifted from a strong emphasis on protected areas, toward a wider focus including also matrix management (e.g. Ricketts et al., 2001; Lindenmayer and Franklin, 2002; Debinski, 2006; Gustafsson et al., 2012). In the late 1980s, a new forest management model – retention forestry – was introduced in northwestern North

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America as a response to the need to better integrate wood production and biodiversity (Franklin, 1989), and spread rapidly to other regions of the world (Gustafsson et al., 2012). Retention forestry can be defined as an approach to forest management based on the long-term retention of structures and organisms, such as live and dead trees and small areas of intact forest, at the time of harvest (Lindenmayer et al., 2012). These structures are not removed in future forest management operations and hence undergo natural processes of growth and decay. The retention of different legacies such as dead and living trees on harvested areas is today a very important and widely applied conservation practice, especially in the boreal forest landscape (Heithecker and Halpern, 2006; Martınez Pastur et al., 2009; Gustafsson et al., 2010; Lindenmayer et al., 2012; Runnel et al., 2013).

Areas exempted from felling through protection or retained in cutting operations can be considered as a continuum of area set-asides, spanning across a range of spatial scales. At the smallest scale, single trees can be retained, dispersed in the harvesting unit. Retained trees can also be left aggregated in small groups (mainly <0.5 ha), e.g. in rocky outcrops, along waterways (riparian buffer zones) or toward the margins of the harvesting unit (Gustafsson et al., 2010). Woodland key habitats (WKH) can be considered the next step up on a spatial scale of area set-asides, with an average size in Fennoscandia and Baltic countries in the range of 0.7–4.6 ha (Timonen et al., 2010). Although exact definition and legal status might vary, a WKH is essentially a small habitat patch that is thought to be particularly valuable for maintaining landscape-level biodiversity and therefore exempted from logging. The concept originates from Sweden in 1992 (Nitare and Norén, 1992) and has subsequently been adopted in much of Northern Europe (Timonen et al., 2010).

1.2. Evaluating species responses to conservation measures

In order to evaluate the efficiency of protected areas and area-based conservation measures such as small-scale set-asides in forestry, we need to link the management tools to real-world ecology. In the present study we compared three categories of area-based conservation measures typical of North European forest: *Retention patches*, *woodland key habitats* and *forest reserves*.

All these conservation measures supply dead wood, which is a key substrate in forest and supports a large and unique biodiversity. The distribution and dynamics of the dead wood differ between tree species and decay, which also affects the associated biodiversity. We therefore compared the effect of different area-based conservation measures for two ecological systems: *fungi in late-decay spruce logs* and *beetles in early-decay aspen snags*.

The dynamics of these systems pose an interesting contrast in the boreal and hemiboreal forest of Northern Europe: on one hand, Norway spruce (*Picea abies*) occurs continuously across large stretches of forest, as spruce is a dominating species in this region. In addition, spruce has a maximum life span of 400–500 years and the decay of large trees can take up to 100 years (Storaunet and Rolstad, 2002). It is well established that many endangered species of fungi are associated with slowly decaying spruce logs in natural forest (Berg et al., 2002; Junninen and Komonen, 2011).

On the other hand, European aspen (*Populus tremula*) occurs dispersed in forests dominated by coniferous species. It is a pioneer species, regenerating after forest fire or similar large clearing events, and then gradually being replaced by Norway spruce. It is quite common to find single large senescent aspen trees interspersed in the mature coniferous forest. The lifespan of European aspen is rather short, 80–100 years, and once dead, the wood decays fast. Recently-dead aspen is a short-lived, but important insect habitat, with a number of associated saproxylic beetle species (Siitonen and Martikainen, 1994; Tikkanen et al., 2006).

Previous studies on both fungi and insects have shown that the response to fragmentation may differ between generalist (eurytopic) and specialist (stenotopic) species (Davies et al., 2004; Driscoll and Weir, 2005; Stokland and Larsson, 2011; Nordén et al., 2013). Therefore we analyzed the response of the species specialized to the habitats in question, separately from the response of generalist species with broad habitat preferences. In a combined observational and experimental setup in four landscapes in Southern Norway, we addressed the following questions for the two systems:

(1) Do similar late-decay spruce logs support *the same species richness* and *assemblages* of fungi in retention set-asides, woodland key habitats and forest reserves? Is the response different between generalists and specialists?
(2) Do replicated units of early decay aspen serve as habitat for *the same species richness* and *assemblages* of beetles, regardless of which area-based conservation measure they are placed in? Is the response different between generalists and specialists?

We expected more difference between set-aside categories for habitat specialists, as they are expected to be more sensitive to fragmentation than habitat generalists. If that is the case, retention set-asides should host fewer specialists than WKHs, and WKHs should house fewer than reserves. Finally, we predicted that the difference will be greater for specialized late-decay fungi in spruce than for specialized early-decay beetles in aspen, due to the larger need for stability in space and time of late decay systems.

2. Materials and methods

2.1. Study areas and site selection

The study was conducted in Southern Norway, in the southern or middle boreal vegetation zone (Moen, 1998), and consisted of forest dominated by spruce, with birch (*Betula pubescens*), aspen (*P. tremula*), and sometimes Scots pine (*Pinus sylvestris*) as subdominants.

The study was conducted in four different landscapes; Losby Bruk in Østmarka (mainly Lørenskog municipality, Lat. 59.89, Long. 10.97, 150–300 masl), Oslo municipal forests in Nordmarka (Lat. 60.00, Long. 10.71, 200–500 m), Selvik Bruk in Vestskogen (Drammen/Sande municipalities, Lat. 59.68, Long. 10.12, 130–200 masl) and Gran Almenning and Mathiesen/Eidsvold Værk in Hadelands østås (Gran/Hurdal municipalities, Lat. 60.36, Long. 10.75, 500–700 masl). The field work was conducted between 2006 and 2011.

All forest holdings were certified through the PEFC Norway, as is almost all forest in Norway http://www.pefcnorge.org/. This implies that important woodland key habitats for forest biodiversity (selected by the Complementary Hotspot Inventory method (Gjerde et al., 2007), average size 1 ha (Timonen et al., 2010), making up 1.5% of productive forest (Søgaard et al., 2012)) has been designated and set aside on all properties. Similarly, retention trees and retention patches have been left at final felling (4–6 years before onset of the study) both along mires, streams or lakes and in the felling area in general, measuring 0.5–1 tree per ha of clear-cutting and with a mean size less than 0.5 ha. All studied landscapes included a forest reserve, making up 3–7% of the study areas.

In each of the study landscapes we set up a block design representing three different area-based conservation measures typical of North European forest: retention set-asides (RET), woodland key habitats (WKH) and strict nature reserves (NAT). Each block was replicated 8 times within each landscape, giving a total