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Evaluating the influence of integrative forest management on old-growth habitat structures in a temperate forest region

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ABSTRACT

Integrative forest management attempts to simultaneously fulfill both wood production and biodiversity conservation in a given forest region, and presumably supplants the need for unmanaged forest reserves. This is the dominant management paradigm in the temperate zone of Europe, yet few studies have examined the validity of this approach. We used Slovenia as a test bed to examine how the long-term practice of integrative forest management has influenced two structural components of mature forest conditions, namely coarse woody debris (CWD) and large living trees, as well as the distribution of the White-backed Woodpecker, a species dependent on such conditions. Data were compiled from national inventory plots, coupled with separate surveys in 51 forest reserves. The mean volume of CWD and density of large beech trees across managed forests in Slovenia was 15 m^3 ha^{-1} and 6 ha^{-1}, respectively; these mean values were significantly higher (165 m^3 ha^{-1} and 55 ha^{-1}) in old-growth reserves. CWD was primarily comprised of small diameter pieces in managed forest, whereas large diameter pieces in multiple stages of decay represented most of the volume in reserves. These results, coupled with the limited distribution of the woodpecker across the country, suggest that integrative management practiced over a large scale may be insufficient for maintaining biodiversity dependent on mature forest conditions at current levels of wood extraction.

1. Introduction

The world's forests are indispensably linked to the wellbeing of humanity (Costanza et al., 1997). They harbor about two thirds of terrestrial biodiversity, play an integral role in climate regulation and biogeochemical cycling, and provide timber, fuelwood, and numerous non-timber products for billions of people (Millennium Ecosystem Assessment, 2005). As the human population grows, forests across the globe will face increasing pressure to provide these essential goods, while also maintaining their ability to provision various services. Striking the balance between these two sets of contrasting functions is perhaps one of the greatest challenges for managing forests worldwide.

To this end, much effort has examined how various systems of management within production forests influence nontimber services, particularly forest biodiversity. It is now widely accepted that some form of ecologically based forestry should be employed to ensure conservation of biodiversity (Lindenmayer and Franklin, 2002; Mori et al., 2017). Although the goals and types of ecological forestry vary, a central theme is that the structures and processes in forests managed for timber production should reasonably resemble those found in primary forests, the idea being that native biodiversity is adapted to unmanaged forest ecosystems that have developed under a regime of natural disturbances (Franklin et al., 2002; Hunter, 1993; Kuuluvainen, 2002; Lindenmayer et al., 2012). An alternative approach to conserving forest biodiversity is simply to remove forest regions from production management, thereby protecting or restoring primary forests, balanced with more intensive timber production (e.g. plantations) in separate regions (Paquette and Messier, 2010).

These two contrasting approaches are often referred to as integrative and segregative forest management and represent ends on a continuum of potential zoning of economic versus ecological functions in a given forest region (Boncina, 2011; Hartmann et al., 2010; Paquette

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and Messier, 2010). Taken to an extreme, integrative forest management would simultaneously fulfill both timber production and conservation of native forest biodiversity using widespread, but low intensity logging over an entire region, thereby supplanting the need for protected forest reserves. The opposite extreme would be to segregate half of a region's forests into plantations of fast growing trees for timber production and protect the remaining forests in reserves.

Decisions regarding the proportion of forest area under integrated and segregated management across large regions are likely to have more important consequences on forest biodiversity than the type of stand-level silvicultural system used within a given management zone. However, there are few empirical studies that have explicitly examined this on a large scale over a sufficient period of time (but see Tittler et al., 2015). Simulation studies indicate that a segregated approach, namely one that allocates forest area into protected reserves, zones with ecologically based forestry, and zones with intensive wood production (i.e. Triad forest management, (Seymour and Hunter, 1992), can allow for more protected area (and therefore more old-growth) without incurring losses in timber production (Côté et al., 2010; Tittler et al., 2012).

Balancing economic and ecological functions of forests is especially relevant in Europe, where a long history of relatively intensive forest management has nearly eliminated old-growth conditions across most of the region. Yet there is also a clear societal interest to maintain biodiversity, which is well exemplified by Europe's flagship conservation program, Natura 2000, an approach that is largely based on integrated management. Concurrently, national forest agencies among many European countries are advocating a future path toward more integrated forest management (Bauhus et al., 2013; Forest Strategy 2020, 2011). The use of widespread integrative forest management, coupled with the lack of old-growth conditions across the contemporary landscape, could have important implications for conservation of biodiversity. Recent studies in beech dominated forests of Europe, for example, document that integrative nature-based management has led to alterations in communities of fungi and beetles (Bässler et al., 2014; Gossner et al., 2013).

This is particularly important in the temperate region of Europe, where mixed mesophytic forests are the dominant forest type. The predominant natural disturbance regime in this region is characterized by small-scale disturbances that are relatively stable in space and time (i.e. gap dynamics), punctuated by periodic intermediate severity events; disturbance events that are both large and severe are rare (Hobi et al., 2015; Kulakowski et al., 2017; Nagel et al., 2016; Splechtna et al., 2005). In the absence of human influence, we would expect a large part of the landscape to be in an old-growth stage of development under such a disturbance regime (Frelich and Lorimer, 1991). Consequently, species that are restricted to old-growth conditions, especially those dependent on a sufficient amount and quality of coarse woody debris (CWD) and veteran trees with unique microhabitats (e.g. saproxylic species of fungi, lichens, bryophytes, insects, birds, and bats), have experienced substantial declines, many of which are estimated to be on the verge of extinction or have already gone extinct over much of their range (Brunet et al., 2010; Lassauce et al., 2011; Nieto and Alexander, 2010; Speight, 1989). Presumably, integrative forest management should be sufficient to maintain many of these species.

Slovenia provides a unique long-term experiment to examine the utility of widespread integrative forest management with regard to conservation of biodiversity associated with old-growth forest conditions. Both within Europe and worldwide, Slovenia is among the best examples of long-term integrative forest management on a national scale. Forests cover about 60% of the country and are managed with what is commonly referred to as *close-to-nature* management, a form of continuous cover forestry. This type of management is characterized by native tree species, a reliance on natural regeneration, and use of relatively small-scale silvicultural systems (Bauhus et al., 2013; Schütz et al., 2016); clear cutting is prohibited by law in Slovenia. Close-to-nature management in Slovenia has been carried out for approximately 70 years (Diaci, 2006), during which time there has been strong oversight by the country's national forest service. Forest regulations require that CWD make up at least 3% of total wood volume. Because of the reliance on widespread integrative management to fulfill both economic and ecological functions, the network of protected forest reserves covers < 1% of the total forest area.

We examined common structural components associated with old-growth, namely CWD (downed and standing dead trees) characteristics and large living trees, across Slovenia's national scale forest management inventory, as well as from 51 forest reserves spanning a range of naturalness. We ask how integrative forest management has influenced the quantity and quality of CWD and large trees across the country. In addition to the forest structural data, we examined recent survey data of the White-backed Woodpecker (*Dendrocopos leucotos lilfordi*), a species indicative of old-growth conditions in beech (*Fagus sylvatica*) dominated forests, and discuss the influence of integrative forest management on its current distribution in Slovenia.

2. Methods

2.1. Study area and indicator species

Forest communities in Slovenia are typical of the mixed-mesophytic forests found throughout much of the European temperate zone. The dominant forest types include beech, beech-fir (*Abies alba*), and beech-oak (*Quercus petraea*) communities. Although these forest types represent most of the forest cover in Slovenia, approximately 15% of the total forest area is dominated by Norway spruce (*Picea abies*), largely the result of planting over the past century in areas that would otherwise be dominated by broad-leaf forests. The vast majority of forests in Slovenia are managed for timber production, although with varying levels of intensity. In state owned forestland, the allowable cut (limited to the annual growth increment of timber volume) is routinely harvested during regular stand entries, while on private land harvesting varies from the maximum allowable cut to low intensity firewood collection. Management in all forests, regardless of ownership, is regulated by the national forest service. Because management is based on the principles of close-to-nature forestry, most forest stands have uneven-aged structures, and partially resemble the structures that would be expected to develop under natural processes.

Biodiversity conservation is integrated with timber production within managed forests, and is assumed to be fulfilled via the principles of close-to-nature management. Due to the relatively well-preserved character of forests (i.e. dominance of native tree species and uneven-aged structure), a large proportion (45%) of forestland in Slovenia is designated as Natura 2000, the European wide network of areas with special legislation designed to protect threatened habitats and species across the continent (Fig. 1). It is worth pointing out that the historical development of close-to-nature management in Slovenia was not for conservation of biodiversity, but rather driven by a response to the negative consequences of intensive forest exploitation and the susceptibility of shallow calcareous soils to erosion (Diaci, 2006).

The network of national forest reserves in Slovenia consists of 164 reserves (Fig. 1), most of which were established during the 1970s, except for a handful of old-growth reserves that were protected earlier in the 20th century. These reserves are the only forest ecosystems in the country where forest management is prohibited by law. The network was originally established to serve as a control for forest management and for research purposes, and less so for biodiversity conservation (Mlinsek et al., 1980). Most of the reserves are small (< 20 ha) and together make up < 1% of the total forest area in the country; 16 forest reserves are classified as old-growth (Nagel et al., 2012), which collectively represent 0.07% of the total forest area (Fig. 1).

The indicator species used in this study, the White-backed Woodpecker (hereafter “woodpecker”), was selected because 1)