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Can landscape-level ecological restoration influence fire risk? A spatially-explicit assessment of a northern temperate-southern boreal forest landscape

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ABSTRACT

Management strategies to restore forest landscapes are often designed to concurrently reduce fire risk. However, the compatibility of these two objectives is not always clear, and uncoordinated management among landowners may have unintended consequences. We used a forest landscape simulation model to compare the effects of contemporary management and hypothetical restoration alternatives on fire risk in northern temperate and southern boreal forests of the Border Lakes Region in Minnesota, USA, and Ontario, Canada. Six main model scenarios simulated different combinations of timber harvest, fire exclusion, wildland fire use, and prescribed fire. Mean fire risk values were calculated as a function of high risk fuel type occurrence, fire events, and windthrow events over model time, and were compared among scenarios and among major management areas. Our model results indicate that a continuation of contemporary management, with limited wildland fire use, would increase fire risk over time and lead to greater continuity of high-risk fuel types in parks and wilderness areas. Compared to the contemporary management scenario, greater use of wildland fire in a historical natural disturbance scenario and three alternative restoration scenarios resulted in less spatially aggregated high-risk fuels over time and lower long-term fire risk in parks and wilderness. Outside of parks and wilderness, prescribed fire with logging was effective at reducing fire risk on portions of the landscape in two restoration scenarios, largely by maintaining deciduous tree dominance and fire-tolerant red and white pine stands, and timber harvest alone maintained patches of less fire-prone deciduous forests in some scenarios. However, forest restoration and fire risk objectives were not always compatible, especially when restoration of fire-prone forest conflicted with the goal of reducing risk of large, severe fires. Both fire risk reduction and forest restoration objectives will benefit from spatially coordinated, landscape-level planning among landowners.

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1. Introduction

Reintroduction of fire is central to many forest restoration efforts, both as a tool to achieve desired objectives and ostensibly to minimize fire risk through reductions in fuel loads and fire-prone fuel types (Allen et al., 2002). Large conservation reserves containing fire-dependent ecosystems may provide practical opportunities for the use of wildland fire to meet restoration objectives (Baker, 1994; Kneeshaw and Gauthier, 2003), while adjacent, intensively-managed or human-dominated landscapes may require silvicultural or prescribed fire strategies (Lindenmayer et al., 2006). However, disparate forest management activities among landowners or management areas can create sharply contrasting landscape patterns of forest composition (Tinker et al., 2003) and fuel types (Drobyshev et al., 2008). Unintended consequences of spatially uncoordinated activities can detract from meeting forest restoration and fire management objectives at landscape scales and may limit restoration options (Lytle et al., 2006).

It may be particularly important to consider landscape-scale interactions between management activities and spatial arrangement of fire-dependent forest types (Sturtevant et al., 2009a). For instance, restoration of fire-prone ecosystems in parks and wilderness may conflict with objectives to reduce risk of wildfire on adjacent developed areas or commercial timberlands (Radeloff et al., 2005; Suffling et al., 2008). These conflicting objectives may be especially prone in landscapes historically shaped by high-severity, stand-replacing fire regimes, such as boreal forests. Although fire behavior models applied at landscape scales have indicated that strategic modification of fire-prone forest structures through

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timber harvest or prescribed fire may reduce susceptibility to severe fire (e.g., Suffling et al., 2008; Beverly et al., 2009), these studies assume single ownership objectives for the landscape in question. Few studies (e.g., Sturtevant et al., 2009a) have specifically assessed fire-risk across multi-landowner landscapes as a response to disparate ecological restoration strategies.

The goal of this research was to assess the potential effects of regional-scale restoration strategies on fire risk in the heavily forested Border Lakes Region (BLR) of northern Minnesota and northwestern Ontario. We used a forest landscape simulation model to assess the degree to which contemporary management and forest restoration alternatives, as modeled and presented previously for the BLR by Shinneman et al. (2010), might differ over time in their potential influence on three fire variables: fire occurrence, fuel type distributions, and mean fire risk (the latter defined by potential interactions between fire occurrence and fuel types). To investigate the response of these three variables, we compared six alternative management scenarios that included various combinations of contemporary forest harvest, restoration activities, and wildfire use. For two restoration scenarios, we also tested the potential to reduce fire risk in portions of the landscape, where stand-replacing fire is less desirable, by using prescribed fire in hypothetical management zones that straddle boundaries of park and wilderness areas adjacent to developed areas and more intensively harvested timberlands. Comparing the potential effects of alternative management and restoration scenarios may be particularly useful in the BLR, where several major landowners are seeking to move fire-prone forest ecosystems toward their ranges of natural variability via different strategies (Ontario Ministry of Natural Resources, 2001; Minnesota Forest Resources Council, 2003), while reducing fire risk to timberlands and developed areas (USDA Forest Service, 2004).

2. Modeling approach and methods

The ~2.1 million ha Border Lakes Region (BLR) in northern Minnesota and northwestern Ontario (Fig. 1) occupies a transition zone between northern temperate and southern boreal forests, with warm, short summers and long, cold winters (Heinselman, 1996). An area of modest topographic relief, the shallow soils of the BLR are underlain by glacially-scoured Precambrian bedrock of the Canadian Shield. Freshwater lakes are a prominent feature of the landscape. Common conifer tree species include jack pine (*Pinus banksiana*), black spruce (*Picea mariana*), white spruce (*Picea glauca*), balsam fir (*Abies balsamea*), red pine (*Pinus resinosa*), white pine (*Pinus strobus*), white cedar (*Thuja occidentalis*), and tamarack (*Larix laricina*). Deciduous trees mainly include paper birch (*Betula papyrifera*), aspen (*Populus tremuloides*, *P. grandidentata*), balsam poplar (*P. balsamifera*), red maple (*Acer rubrum*), black ash (*Fraxinus nigra*) and, in the southwestern portion, northern pin oak (*Quercus ellipsoidalis*).

Prior to EuroAmerican settlement, a stand-replacing fire regime supported fire-adapted, early-successional species, including jack pine, aspen, and paper birch. Stand replacing fire sizes were generally 400–4000 ha, but some likely exceeded 100,000 ha (Heinselman, 1973, 1996). Mean fire rotation was ~50–75 years for jack pine-black spruce forests and ~75–150 years for wetland (e.g., spruce bogs) and mixed-wood (aspen-birch-spruce-fir) forest types (Heinselman, 1973; Beverly and Martell, 2003). Some areas experienced longer fire-free intervals that supported late-successional forests of spruce, fir, and cedar (Heinselman, 1973; Frelich and Reich, 1995). Old white pine and red pine stands were likely maintained by smaller (40–400 ha), low- to moderate-severity fires that occurred every 5–100 years on average, but also experienced severe crown fires every 150–350 years (Heinselman,

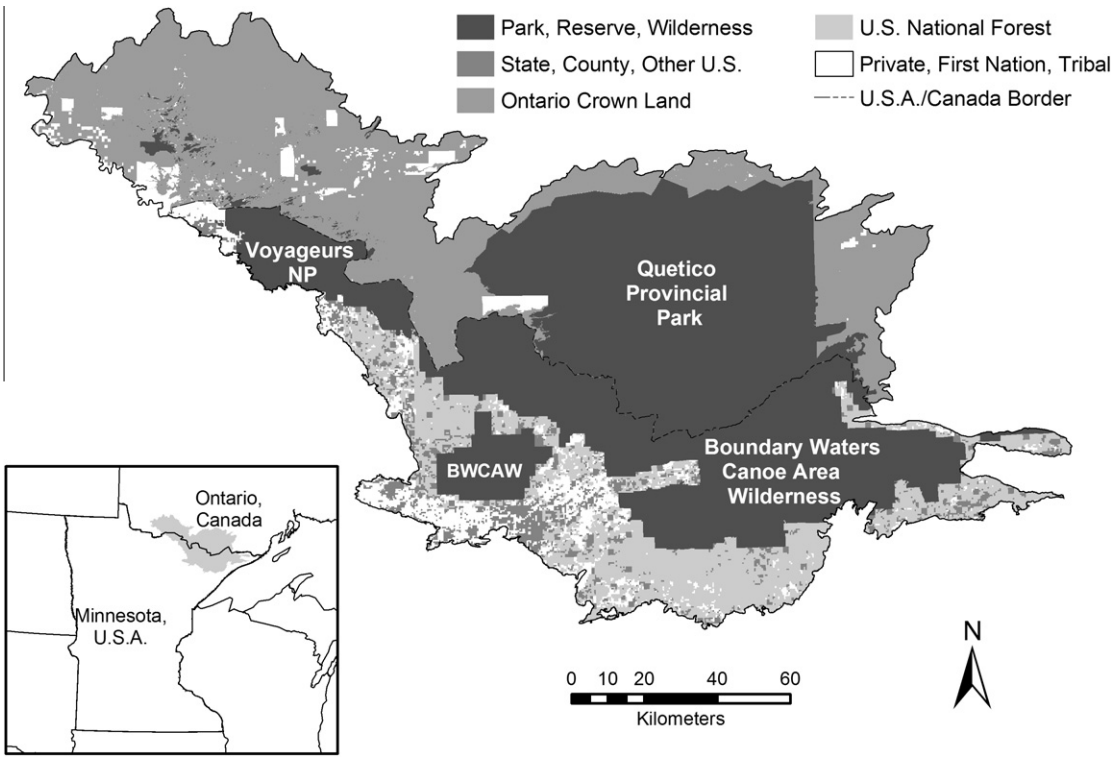

Fig. 1. The Border Lakes Region and major land ownership. NP = National Park; BWCAW = Boundary Waters Canoe Area Wilderness. Parks and wilderness areas are largely undeveloped, private lands within the BLR have generally scattered or lakeshore development, including a few small towns, and most of the remainder of the region is primarily managed for timber harvest.