approximation to the need for edge protection. The location of relatively isolated woods in the 10-30 ha size range might be priorities for habitat expansion. Areas with little woodland might be targeted for 'seeding' with boundary strips and small woods. Further development of mixed models is desirable; species movement is important for long-term survival, but depends on survival in the short to medium term. These in turn may depend more on the edge protection and habitat expansion functions in intensively-managed landscapes.

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POSTERS

Linking ecological and structured decision-making networks to develop local- and landscape-scale restoration strategies for mixed-pine forests of Upper Michigan, USA

P.C. Goebel[1], D.M. Hix[2], R.S. Wilson[2], R.G. Corace, III[3]

[1]School of Environment and Natural Resources, Ohio Agricultural Research and Development Centre, The Ohio State University, 1680 Madison Ave., Wooster, OH 44691, USA. Email: goebel.11@osu.edu.

[2]School of Environment and Natural Resources, The Ohio State University, 2021 Coffey Rd., Columbus, OH 43210-1085, USA.

[3]Seney National Wildlife Refuge, U.S. Fish and Wildlife Service, 1674 Refuge Entrance Rd., Seney, MI 49883, USA.

Abstract

Logging, catastrophic wildfires, fire suppression and land conversion have resulted in significant modifications to the once-extensive mixed-pine forests of the northern Lake States, U.S.A. Fire is known to have been an important factor regulating their development; therefore, many federal, state and non-profit organisations are looking for guidance to help with restoration efforts for these forest ecosystems. To meet these needs, we initiated a study to examine the role of natural fire in shaping the ecological characteristics of these forest ecosystems and how this information could be used to inform decision making related to local and landscape restoration efforts. Despite the consensus among organisations regarding their fundamental objectives, there are institutional barriers that may make it difficult for these organisations to coordinate large-scale restoration efforts, including the practical implementation of prescribed fire. Our approach will help reduce this uncertainty and provide a framework for managers to coordinate their efforts via a restoration network.

Keywords: ecosystem restoration, fire, forest stand dynamics, resource management

Introduction

Fire-maintained mixed-pine forest ecosystems composed of eastern white pine (*Pinus strobus* L.), red pine (*P. resinosa* Ait.), and jack pine (*P. banksiana* Lamb.) once dominated the landscape of the northern Lake States, U.S.A. These forest ecosystems were important not only from an ecological perspective in terms of biological diversity and wildlife habitat, but they also provided important cultural resources for many Native American communities. From the land-survey and historical records, it is believed that frequent, low-intensity surface fires maintained a relatively open understory which over time maintained mixed-pine stands with uneven-aged structures (Zhang *et al.*, 2000). Under certain conditions (*e.g.* low fuel moisture, low humidity, high temperatures, and strong winds), these fires sometimes

intensified and became stand-replacing disturbance events. Over the past century, logging, catastrophic wildfires, land conversion and subsequent fire suppression have changed these forests dramatically. For example, overall stem densities of jack pine and other fire-sensitive hardwoods are much higher now than when compared with the pre Euro-American conditions (Zhang *et al.*, 2000). Additionally, changes in the fire regimes have resulted in significant accumulations of fuels that under the right climatic conditions may pose a serious threat to some local communities.

Currently, resource managers and policy makers from federal, state and non-profit organisations are looking for strategies to reduce fire hazards in fire-maintained mixed-pine forest ecosystems (Crow and Perera, 2004). These strategies range from restoring fire in these ecosystems, or alternatively, designing silvicultural systems that emulate the effects of fire on ecosystem patterns and processes. The biological legacies of active fire suppression efforts over the past 80 years, however, have made the use of fire as a fuel reduction and restoration tool potentially hazardous and possibly ineffective. Consequently, adaptive management activities designed to emulate natural disturbances may be the most effective methods of reducing the high fuel loads and restoring the composition and structure of these once extensive and culturally important forest ecosystems.

To support the development of new adaptive management systems, we need a better understanding of how past fire regimes (and the factors that regulate wildland and prescribed fire) influence current forest ecosystem composition, structure, and fuel loadings. Such investigations into past disturbances and the biological legacies resulting from these disturbances, can provide much-needed information on the successional pathways and potential success of management systems intended to help restore ecosystem processes at both local and landscape scales. In addition to understanding the factors that regulate the accumulation of fuels and potential fire hazards, an analysis of the forest management goals and objectives of different federal, state, and non-profit organisations is needed to inform decision-making among a network of organisations that are focused on the reduction of fuels and restoration of important landscape processes, such as fire, that are critical to the maintenance of mixed-pine forest ecosystems.

In this paper, we describe our current efforts to: 1) better understand the role of natural and human disturbances in regulating the composition and structure of mixed-pine forest ecosystems in the eastern Upper Peninsula of Michigan, U.S.A.; 2) identify the key benefits, objectives and perceived risks associated with forest ecosystem restoration across ownerships of the region; and 3) describe our approach to identify alternatives that land managers as part of this network may consider when making fuel reduction and mixed-pine forest ecosystem restoration decisions.

Fire and forest composition and structure

Our efforts to date have focused on the 38,531 ha Seney National Wildlife Refuge (SNWR), a landscape characterised by glacial outwash channels and a matrix of patterned fens, interspersed by sand ridges in the eastern Upper Peninsula of Michigan, U.S.A. (figure 1). The disturbance history of mixed-pine forest ecosystems at SNWR has been varied. Many stands located within the Seney Wilderness Area (figure 1) are considered old-growth and represent the best examples of relatively undisturbed mixed-pine forest ecosystems in the northern Lake States region.

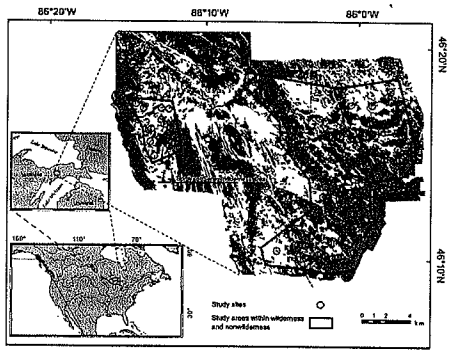

Figure 1. Wilderness and non-wilderness portions of Seney National Wildlife Refuge with sample locations (open circles) in the eastern Upper Peninsula of Michigan, U.S.A. Darker areas indicate forest cover, while white areas on Refuge map indicate patterned fens or other marshlands.

Other portions of the SNWR landscape are more typical of the region, having experienced heavy exploitation following logging after settlement in the 1860s, catastrophic slash fires in the 1890s and early 1900s and then a long period of active fire suppression and management beginning in the 1930s.

Using this general disturbance history as a guide, we dendrochronologically reconstructed the fire regime of mixed-pine forest ecosystems at SNWR (Drobyshev *et al.*, 2008a). These analyses suggest that large (5,000-10,000 ha) non-stand replacing surface fires were characteristic of the natural fire regime and following Euro-American settlement, there was a decrease in overall fire frequency where smaller (< 100 ha) fires became more common. In terms of variability, we found that the fire cycle of stands located in the Seney Wilderness Area was longer and more variable than stands located outside of the Seney Wilderness Area, which were subjected to higher levels of direct human influence (*e.g.* logging and fire suppression). We also quantified the variation in stand composition, structure and diversity and examined how this variability was related to current fuel loadings, fire history and harvesting history (Drobyshev *et al.*, 2008b). These results suggest that, in terms of forest composition and structure, those stands that have experienced long, fire-free periods have higher abundances of jack pine and a lower overstory/understorey structural diversity in comparison to those stands that experience more frequent fire events. Additionally, we found that multi-cohort stands with old (250–300 years) trees in the overstory experienced more frequent fires and as a result are more structurally complex than younger stands. Finally, although we observed no significant relationships between total coarse woody debris and fire history, we did find that stands which experienced repeated low-intensity fires showed significantly smaller amounts of fine woody debris and shallower duff depths.

Key management objectives, and perceived benefits and risks of using fire

In order to identify the key management objectives and perceived risks and benefits of restoring mixed-pine forest ecosystems in the eastern Upper Peninsula of Michigan, we conducted open-ended interviews with thirteen land managers associated with the U.S. Department of Interior Fish and Wildlife Service, U.S. Department of Agriculture Forest Service, Michigan Department of Natural Resources and The Nature Conservancy (Wilson *et al.*, 2009). These interviews indicate that as far as mixed-pine forest ecosystem management and restoration is concerned, ecologically motivated objectives (*e.g.*, wildlife and habitat diversity) take precedence over socio-economically motivated objectives (*e.g.* providing forest products). The reverse is true for minimising adverse effects of wildfire, where socio-economic objectives such as protecting property take precedence over ecological objectives like biodiversity. Despite interest in restoring fire, or using fire as one of many tools to help emulate the outcomes of natural disturbance, managers of all organisations felt limited by uncertainty about the potential risks and benefits to their fundamental management objectives. Difficult tradeoffs between short-term and long-term objectives and significant external barriers (*e.g.* mandates, lack of knowledge) were perceived to be present. When these difficult trade offs are combined with uncertainty about the factors that regulate ecosystem structure the default decision may be to rely on decision short-cuts that result in the avoidance of the perceived "risky" choice (*e.g.* prescribed fire) and work alone rather than as part of an ecological management network.

Developing restoration strategies and a restoration network

The diverse land ownership goals and mandates of land management organisations in the eastern Upper Peninsula of Michigan makes it unlikely that restoration efforts conducted at local scales will adequately emulate the effects of larger, landscape-scale fires, which were critical to the development of mixed-pine forests on the pre Euro-American landscape. Additionally, we also found that institutional barriers may make it difficult for these organisations to coordinate large-scale restoration efforts, including the practical implementation of a wildland fire-use approach or prescribed fire. Currently, we are continuing our efforts to foster the restoration of mixed-pine forest ecosystems through the use of a structured decision-making approach. Our previous work has helped identify the fundamental management objectives and potential management alternatives that may be useful for achieving what is ultimately most important for individual agencies and organisations. We are now working to characterise the impacts or consequences of these management alternatives on the stated objectives identified by individual organisations employing the best available scientific or technical data. Once these consequences have been established, then a complete decision-support tool can be provided to the various managing authorities to assist in making necessary trade-offs and ultimately more informed decisions within a larger forest ecosystem restoration network.

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Edited by:

Roger Catchpole[1], Richard Smithers[2], Phil Baarda[3], Amy Eycott[4]

[1] ARM, Evidence Team, Natural England, Government Buildings, Lawnswood, Leeds, LS16 5QT. [2] Woodland Trust, Autumn Park, Grantham, Lincolnshire, NG31 6LL. [3] Scottish Natural Heritage, Great Glen House, Leachkin Road, Inverness, IV3 8NW. [4] Forest Research, Alice Holt Lodge, Farnham, Surrey, GU10 4LH.

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