Using fire history, vegetation and risk analyses to develop integrated strategies for mixed-pine forest restoration in Upper Michigan

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Background & Objectives

Mixed-pine forest ecosystems composed of red pine (*Pinus resinosa* Ait.), eastern white pine (*P. strobus* L.), and jack pine (*P. banksiana* Lamb.) once dominated the landscape of the northern Lake States, covering almost 40% of eastern Upper Michigan. From the land-survey and historical records, it is believed that low-intensity surface fires maintained these forest ecosystems, creating small gaps, maintaining a relatively open understory, and over time producing complex age and spatial structures. However, the legacies of turn-of-the-century logging, catastrophic wildfires, and fire suppression have resulted in altered structures, and increased fuel loadings that have reached potentially dangerous levels. To better understand how these legacies have influenced these forest ecosystems, we are quantifying the differences in fire-history regimes, fuel loadings, and forest compositions and structures between pre-European settlement and post-settlement mixed-pine forest ecosystems. Concurrently, we are examining the current fire hazard and forest management planning efforts of different land management agencies in the region, including the USDI Fish and Wildlife Service, USDA Forest Service, Michigan Department of Natural Resources, and The Nature Conservancy.

Our overall goal with this integrated research program is to develop restoration-based fuel reduction recommendations for mixed-pine forest ecosystems of eastern Upper Michigan. Our specific objectives are to:

1) develop a better understanding of the fire-history regimes, fuel loadings, and forest composition and structural characteristics of pre-European settlement and post-settlement mixed-pine forests;

2) analyze the current fire hazards and the forest management planning efforts of the different agencies responsible for the stewardship of mixed-pine forest ecosystems; and

3) develop restoration-based fuel reduction recommendations for mixed-pine forest ecosystems of eastern Upper Michigan.

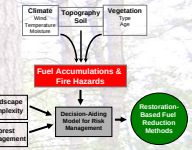
Approach

To accomplish these objectives, we are using an integrative model (see right) that is focused on developing a detailed record of the pre-European settlement and post-settlement fire regimes, and estimated fuel loadings and structures of the current mixed-pine forest ecosystems of the Seney Sand Plain Ecoregion of Upper Michigan. We are also examining the current management objectives and fire hazard risks facing resource agencies responsible for the management of mixed-pine forest ecosystems. Once complete, we will develop a decision-aiding model for fire risk management and design fuel reduction methods that emulate the historical effects of fire and restore the composition and structure of mixed-pine forest ecosystems.

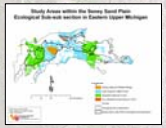
In 2006, we conducted our work at the Seney National Wildlife Refuge and in 2007 we sampled mixed-pine forest ecosystems on TNC's Two-Hearted River Forest Reserve and the Hiawatha National Forest. In each study area, reference stands (minimally disturbed old-growth stands where the fire regime has remained largely intact) and disturbed areas were sampled. We collected wedge samples from both fire-scarred live and dead trees to examine the fire history of each stand, while standard inventory methods were used to quantify differences in stand composition, structure, and fuel loadings. In 2007 and 2008, we also conducted extensive interviews with key land managers associated with the different federal, state, and private land owners to gauge their interest in restoration, their use of fire as a management tool, and their concerns regarding the potential use of prescribed fire to reduce fuel loadings.

A dense jack pine stand that has developed on a former mixed-pine site in the absence of fire.

An old-growth mixed-pine stand that has experienced frequent surface fires.



Integrated model being used to develop restoration-based fuel reduction methods for mixed-pine forests of Upper Michigan. We are conducting detailed studies of the fire history and influence on vegetation structure and fuels, which when combined with information about the landscape and forest management complexity, will feed into a decision-aiding model for risk management.



Key Results to Date

Fire History

Our results, based on extensive fire-scar analyses, suggest that the natural fire regimes of mixed-pine forest ecosystems in eastern Upper Michigan were dominated by frequent small (< 100 ha) fires with a fire-return interval (FRI) of 20-30 years and large (5,000-10,000 ha) surface fires with a FRI of 50-70 years (*Drobyshev et al. 2008a*). Most large fires occurred in the late summer or early fall, and major fire years were 1754, 1791, 1864, 1891, 1910, 1919, and 1976. Fire regimes differ slightly by landform, with more frequent fires on outwash channels than sand ridges. Additionally, the characteristics of the fire regime changed dramatically with European settlement. For example, the fire cycle (FC) was shortest in the post-settlement period of 1860-1934 (FC=30 years), and has subsequently increased with the emphasis on fire suppression from 1935-2006 (FC=149-1,090 years). See Drobyshev *et al.* (2008a) for more information.

Drobyshev, I., P.C. Goebel, D.M. Hix, R.G. Corace, III, and M.E. Semko-Duncan. 2008a. Pre- and post-European settlement fire history of red pine dominated forest ecosystems of Seney National Wildlife Refuge, Upper Michigan. *Canadian Journal of Forest Research*. (in press).

Legacies of Fire and Past Harvesting on Stand Structure and Fuel Loadings

In terms of stand structure and fuel loadings, our analyses show that stands with the history of cutting clearly differentiate themselves by a high abundance of jack pine and lower structural diversity of the overstory and understory vegetation. Stands which experienced repeated fires, however, showed reduced plant diversity, lower amounts of fine woody debris, and shallower duff depth. No relationship was found between fire history and the amount of coarse woody debris (CWD) and litter. However, CWD did increase in multi-cohort stands with high variation in diameter distribution. Finally, litter depth was higher in both jack pine-dominated, harvested stands and structurally diverse fire-prone red pine stands. See Drobyshev *et al.* (2008b) for more information.

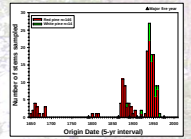
Using a total of 200 samples (160 increment cores and 40 partial cross-sections) from red pine and eastern white pine stems in old-growth mixed-pine stands of the Seney Wilderness Area, we have determined that these stands are uneven-aged. Most recruitment to sample height occurred following major fires with pulses of regeneration following known fire events. Additionally, analyses of samples dated from 1652-2006 suggests that the majority of stems sampled experienced prolonged periods of growth decreases in the absence of fire, while following fire some stems experienced growth increases most likely related to some form of canopy disturbance, while other stems experienced growth decreases. Although these old-growth mixed-pine forest ecosystems are structurally diverse and are relatively open-canopied, our analyses suggest that almost half of the stems experiencing a growth increase do so within 10 years of a fire. Finally, our results also demonstrate that red pine, long considered a shade-intolerant species, can in natural conditions respond to canopy disturbances and increase their radial growth significantly, in some cases over 150 years following establishment.

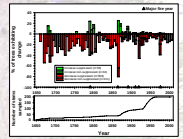
Drobyshev, I., P.C. Goebel, D.M. Hix, R.G. Corace, III, and M.E. Semko-Duncan. 2008b. Interactions among forest composition, structure, fuel loadings and fire history: a case study for red pine-dominated forests of Seney National Wildlife Refuge, Upper Michigan. *Forest Ecology and Management*. (in press).

Risk Analyses

Our analysis of the decision-making process used by federal and state agencies, as well as non-government organizations, when deciding how to manage both natural and prescribed fire suggests that these processes involve complex tradeoffs and are largely driven by both fundamental management objectives and external drivers (e.g., public perception, tradition, industry standards). Our results also suggest that the potential and perceived risks associated with fire vary both within individual organizations as well as among them. Currently, we are working to integrate our ecological analyses with the decision-making analyses to aid land managers in the development of comprehensive restoration-based fuel reduction techniques across the region.

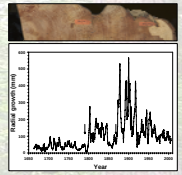
Multiple fire-scarred red pine from Seney National Wildlife Refuge.



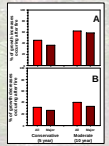


Recruitment date of red pine and white pine stems in old-growth mixed-pine forest ecosystems at Seney National Wildlife Refuge.

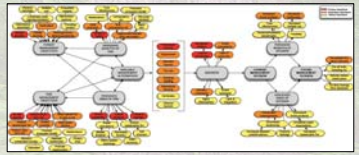
Relative frequency of stems exhibiting a growth increase and (or) decrease in radial growth & number of samples used to determine relative frequency in old-growth mixed-pine forest ecosystems at Seney National Wildlife Refuge.



Red pine sample 95-1 (above) showing two major growth increases following major fires.



Relative frequency of stems showing a growth increase (A) or decrease (B) after fire in old-growth mixed-pine forest ecosystems at Seney National Wildlife Refuge.



Initial decision model developed with input from 13 management professionals. The model outlines the key influences on mixed pine management decisions and highlights the specific objectives, internal and external influences, management alternatives, and perceived risks and benefits mentioned by greater than 20% of the participants interviewed.