

Project Title: Restoration-Based Fuel Reduction Recommendations for Mixed-Pine Forests of Upper Michigan

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Project website: www.pinerestoration.org

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I. Abstract

Mixed-pine forest ecosystems comprised of eastern white pine, red pine, and jack pine once dominated the landscape of the northern Lake States, covering almost 40% of eastern Upper Michigan. However, the legacy of turn-of-the-century logging, catastrophic wildfires, and fire suppression have resulted in increased fuel loadings that have reached potentially dangerous levels. Using an integrated approach, we: 1) developed a better understanding of the fire history regimes, fuel loadings, and forest composition and structural characteristics of pre-EuroAmerican settlement and post-settlement mixed-pine forests; 2) analyzed current fire hazard and forest management planning efforts of the different agencies responsible for the stewardship of mixed-pine forest ecosystems; and 3) began to translate these results into restoration-based fuel reduction recommendations and treatments for mixed-pine forest ecosystems of eastern Upper Michigan.

II. Background and Purpose

Forests dominated by mixed-pines were once a common forest ecosystem type in the northern Lake States. In Michigan, mixed-pine forest ecosystems comprised over 10% (over 1.7 million ha) of the pre-European landscape, and in the eastern Upper Peninsula of Michigan these forest ecosystem types dominated over 38% of the landscape. It is believed that wildfires burned more erratically and less frequently on ice-contact landforms than on xeric, sandy outwash plains (Cleland et al. 2004). As a result, many of the large glacial outwash areas were dominated by pine barren ecosystem types characterized by large unforested openings with pockets of dense jack pine stands and large, interspersed mature red pine and eastern white pine (Whitney 1986; Cleland et al. 2004). However, less is known about the mixed-pine stands dominated by red pine and eastern white pine, jack pine, oaks, aspens and early successional hardwood species that occurred on excessively drained to well-drained ice-contact and outwash channel landforms, which are embedded within a landscape matrix of wetland forests and patterned fens and thus had lower fire return intervals. It is thought low-intensity fires that occurred once every 5-40 years created small gaps or left the basic structure of the overstory unaltered while maintaining a relatively open understory, which over time produced mixed-pine stands with uneven-aged structures (Engstrom and Mann 1991; Loope and Anderton 1998; Cleland et al. 2004). Under certain conditions (e.g., low fuel moisture, low humidity, high temperatures, and strong winds), these fires often intensified and became stand-replacing fires burning not only the mixed-pine forest ecosystem types but also the surrounding forested wetlands and patterned fens. The frequency of stand-replacing fires ranged from 160 years for mixed-pine stands dominated by jack pine, eastern white pine and red pine, to 320 years for stands dominated by eastern white pine and red pine (Zhang et al. 1999). Certainly, insect outbreaks and windthrow from catastrophic storms often created conditions that favored stand-replacing fires. However, regardless of the type of fire, evidence from the Seney Fire of 1976 which burned ~30,000 ha suggests that these stand replacing fires burned irregularly across the landscape with varying degrees of intensity.

The legacy of harvesting, catastrophic fire, and decades of fire suppression has dramatically altered these once important forest ecosystems. While stem densities in the pre-European mixed-pine forest ecosystem types of the eastern Upper Peninsula ranged from 237-322 trees ha⁻¹,

current stem densities are much higher, ranging from 563-692 trees ha⁻¹ (Zhang et al. 1999). Additionally, unlike dry-mesic forest ecosystem types where sugar maple is replacing pine species in the absence of fire (Sturtevant et al. 2004), analysis of Forest Inventory and Analysis (FIA) data reveals that the majority of areas that were once dominated by fire-maintained mixed-pine forest ecosystems are currently dominated by oak and aspen species. These analyses also suggest that less than 10% of these mixed-pine forests compositionally reflect the pre-European condition, and in many instances red pine and white pine are not regenerating successfully as a result of expanding distributions of jack pine, aspen, and oak. Because of the important conservation status of these ecosystems and the highly altered conditions, these forest ecosystems are high priorities for restoration. Furthermore, many of these areas remain a high risk for fire, and as the 1976 Seney Fire demonstrated, under severe drought conditions these ecosystems can act as ignition sources for the adjacent forested wetland and patterned fen ecosystems which can be highly flammable.

As many federal, state, and private land owners focus on reducing the fire hazards associated with pine-dominated forest ecosystem types, it is important to recognize that many of the fuel-reduction treatments that are being considered are compatible with ecological restoration goals – *defined here as the guided recovery of natural composition, structure, and function*. In fact, many forest management and silvicultural options that are being proposed for red pine and white pine management are focused on emulating natural disturbance processes (e.g., Palik and Zasada 2003; Mitchell et al. 2003), a key component of any ecological restoration plan. Inherent in both of these fuel-reduction and restoration activities, there is the recognition that a landscape and regional approach is needed (Palik et al. 2002). However, there historically has been tension between forest management systems oriented towards ecosystem management and forest health (including efforts to reduce fuels) versus those focused on restoring or enhancing ecological integrity (Pimentel et al. 2000). Despite this tendency, a focus on both issues is possible, especially if restoration decisions are adaptive and balance the imposed short-term risks (e.g., associated with prescribed fires and smoke) with long-range benefits (e.g., in terms of ecological benefits or risk reduction). Approaching restoration and risk mitigation decisions in this way requires that resource managers and planners first identify relevant objectives, taking care to separate means from ends (e.g., fuel reduction efforts from restoring ecosystem structure and function). The decision-making process that is employed must also help managers clarify key tradeoffs, including balancing social needs for stability as well as a recognition of the importance of certain natural processes in ecological systems. Given these often conflicting objectives, decisions about environmental restoration activities that are designed to reduce fuel loadings through either the re-introduction of prescribed fire or mechanical activities impose significant cognitive and organizational demands on both forest managers and local stakeholders. Consequently, it is important that these demands be identified and addressed via a carefully structured and adaptive decision-making process that is put in place *before* restoration-based fuel reduction recommendations are developed and implemented (Arvai et al. 2001; Zaksek and Arvai 2004). Our project set out to accomplish these goals and provide a basis for restoration-based fuel reduction activities in mixed-pine forest ecosystem of the eastern Upper Peninsula of Michigan.

III. Study Description and Location

A. Field-based Analyses

The field-based portion of the project focused on the pine forest ecosystems at the Seney National Wildlife Refuge (SNWR). SNWR lies within the Seney Sand Lake Plain Sub-Subsection of eastern Upper Michigan, where poorly drained landforms of lacustrine origin prevail (Albert 1995). The terrain is characterized by glacial outwash channels and a matrix of patterned fens interspersed by sand ridges (Silbernagel et al. 1997). This matrix was formed by the deposition of Valdres glacial outwash, subsequent inundation by earlier stages of the Great Lakes, and drainage of the area during the post-Algonquin period (i.e., 10,000 years BP) (Heinselman 1965). Across the Seney Sand Lake Plain, mixed-pine forest ecosystems tend to be limited to both the outwash channel and sand ridge landforms. At SNWR, outwash channels are typically linear landform types that are associated with streams, and approximately 6-8 km long and several hundred meters to 1 km wide. Sand ridges, however, are smaller features ranging from < 0.5 ha to 5 ha, with most of them being approximately 0.5-2 ha in size and several meters in elevation above the surrounding patterned fen landscape.

Sedge- and shrub-dominated ecosystems, along with mixed coniferous-deciduous forests, dominated the pre-EuroAmerican landscape at SNWR (Comer et al. 1995, Zhang et al. 2000). Particularly, many areas of SNWR were historically dominated by forest ecosystems comprised primarily of red pine, but with a lesser component of eastern white pine and jack pine

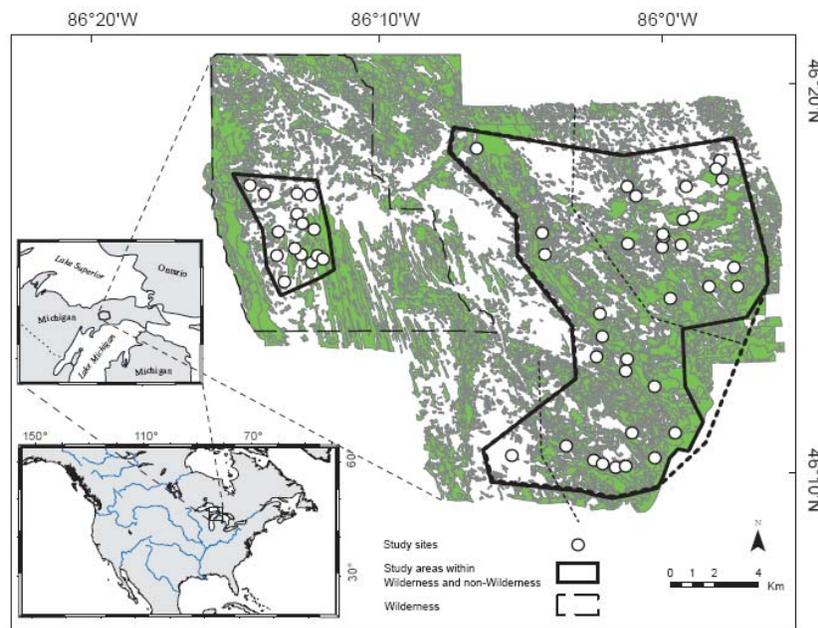


Fig. 1. Location of the Seney National Wildlife Refuge in the eastern Upper Peninsula of Michigan and distribution of study areas and study sites. White areas correspond to anthropogenic waterbodies (e.g., pools) and other wetland-dominated ecosystems.

(Heinselman 1965, Comer et al. 1995). Presently, SNWR is characterized by a wetland-upland mosaic of forest and non-forest cover types (USFWS 2009). The wetland vegetation is typically a sedge- and shrub-matrix. Upland areas are dominated by mixed forests with varying proportions of deciduous species (e.g., American beech (*Fagus grandifolia* Ehrh.), sugar maple and yellow birch (*Betula alleghaniensis* Britton), as well as several coniferous species (e.g., red pine, eastern white pine, jack pine, black spruce (*Picea mariana* (Mill.) B.S.P.), and balsam fir (*Abies balsamea* (L.) Mill)).

Prior to EuroAmerican settlement, fires in pine forests of the upper Great Lakes originated from both lightning and anthropogenic sources (Loope and Anderton 1998). However, by 1851, the General Land Office (GLO) had completed its surveys in eastern Upper Michigan (Barnett 1982), and land sales began shortly thereafter. EuroAmericans moved into the region and large areas were harvested for timber as well as to clear the land for agricultural land uses, and there were subsequent intense slash fires. Maybee (1960) suggests that the approximate onset of logging at SNWR was 1860, focusing first on red and white pine sawtimber. Following this exploitive period, many areas were drained and cleared for agriculture, however poor soil quality and the large-scale intense forest fires fueled by logging debris thwarted these efforts (Losey 2003). This period lasted until the early 1930s, and much of this land was abandoned and tax-reverted to the State of Michigan. In 1935, SNWR was established and forest management practices have been undertaken that focus on providing wildlife habitat.

The research design for the field-based portion of this research focused on contrasting the fire history, forest composition and structure, and fuel loadings between reference and human-impacted stands of both sand ridge and outwash channel landforms. The fire history analyses followed standard dendrochronological methods using fire-scarred wedges collected from both live and dead trees. Forest composition and structure, and fuel loadings, were collected using standard vegetation and Forest Inventory Analysis (FIA) methods. See Drobyshev et al. 2008a, Drobyshev et al. 2008b, and Rist 2008 for more details on the specific sampling and statistical analyses.

B. Stakeholder Interviews

We recruited thirteen land managers from the region representing the following organizations: United States Department of Interior Fish and Wildlife Service (USFWS) ($n = 5$), United States Department of Agriculture Forest Service (USFS) ($n = 3$), The Nature Conservancy (TNC) ($n = 3$), and Michigan Department of Natural Resources (MDNR) ($n = 2$). A larger number of USFWS interviewees were purposefully recruited due to the large role that USFWS plays in the management, and in particular the restoration, of these mixed-pine ecosystems. The interviewees have relatively direct management authority (e.g., they have discretion to implement practices on-the-ground that affect ecosystem composition and structure) in mixed-pine forest ecosystems in eastern Upper Michigan and represent agencies or organizations with different (but often overlapping) mandates.

Each land manager was interviewed for one to two hours and asked the same questions regarding mixed-pine forest management. Interviews provided us with in-depth responses and data not limited by closed-ended survey questions or biased by group interactions in a focus-group

format. Each interview began by obtaining definitions for a list of general forest management-related term, followed by a series of open-ended questions regarding general forest and specific mixed-pine forest ecosystem management objectives, the historic role of fire, the risks and benefits of fire, objectives for managing fire, current forest management strategies and associated risks and benefits they pose to management objectives, and finally future goals for mixed-pine forest ecosystem management and the barriers associated with achieving those goals. See Wilson et al. 2009 for more details on the sampling and statistical analyses used to quantify the decision-making process and risk analyses.

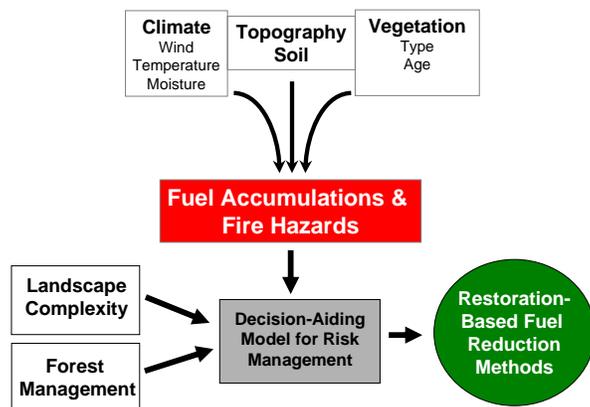


Fig. 2. Major areas of focus leading to the development of fuel treatment guidelines. The focus of this project was understanding the factors that regulate fuel accumulations and fire hazards, and how the decision-making process regarding the management of these fuel accumulations is influenced by landscape complexity and resource management.

IV. Key Findings

The major findings described in this report are associated with 1) field-based investigations and 2) interviews of key stakeholders and experts in the region that form the basis for developing a decision-aiding model of risk management that can lead to restoration-based fuel reduction practices for mixed-pine forest ecosystems (Fig. 2). The goal of this project was to provide information to begin to develop a decision-aiding model for risk management. Below we highlight some of the major findings of the various components; more detailed descriptions of these findings can be found in the various publications listed in the Appendix as well as on the project website www.pinerestoration.org.

A. Historical forest ecosystem types and fire

In an effort to develop more information on the historical composition, structure, and fuel loadings for SNWR, we utilized historical information from GLO records and other geospatial data. Unfortunately, the information we were able to extract from these data was limited as there were few GLO line trees measured on the SNWR landscape. As a result this analysis was expanded to the large landscape of Schoolcraft County, Michigan and we were able to develop a

cohesive ecosystem map developed from the GLO line trees, soils, and topographic information. The results of this analysis suggest that SNWR had consistently lower density and basal area estimates, except in the southeast corner, suggesting that most of this area was probably less forested relative to the rest of Schoolcraft County. Due to the relatively poor resolution of these data, the analyses yielded little new information on the composition and structure of the SNWR forest ecosystems beyond those analyses provided in Zhang et al. (1999) and Zhang et al. (2000), and provided no information on fire history or historical fuel loadings for SNWR.

B. Fire history and forest management effects on fire history

To understand the dynamics of fire in red pine forest ecosystems that once dominated areas of the northern Lake States, we dendrochronologically reconstructed the fire regime prior to EuroAmerican settlement (<1860), after EuroAmerican settlement (1860-1935), and post-refuge establishment (> 1935) for different portions (Wilderness and non-Wilderness) and landforms (sand ridges and outwash channels) of the SNWR (Fig. 1). Using data from 50 sites, we found that the cumulative number of fires showed a slow rate of accumulation in the 1700s to 1859, a steeper pattern suggesting higher fire occurrence from 1860-1935, and a return to fewer fires after 1935. Prior to EuroAmerican settlement, the fire cycle (FC) of sand ridge landforms interspersed within a poorly drained lacustrine plain in the Seney Wilderness Area was 91-144 years. This was longer than on glacial outwash channel landforms (53 years) and on sand ridge landforms interspersed within lacustrine plains located outside of the Wilderness (47 years). The FC was also shorter (30 years) during this period and has subsequently increased (149-1090 years) during the post-SNWR establishment period. Differences in fire regimes among landform types were minor relative to the temporal variation in fire regimes among the three time periods. These results suggest that stand-replacing fires were not common in these mixed-pine forest ecosystems as found in other areas of the northern Lake States and adjacent Canada (Heinselman 1973; Bergeron and Brisson 1990). For more information see Drobyshev et al. (2008a).

C. Fire and forest composition, structure, and fuel loadings

Prior to EuroAmerican settlement, fire played a major role in determining the composition and structure of red pine-dominated forests. However, fire suppression efforts have prevented natural regeneration of red pine and the development of structurally diverse red pine-dominated forests across its natural range. To better understand how past forest history affects the current state of red pine dominated forest ecosystems in Upper Michigan, we quantified the role of forest history on forest structure and fuel loadings on 80 500 m² plots distributed across the SNWR. The majority of the Seney Wilderness Area of SNWR (especially the Strangmoor Bog National Natural Landmark) has experienced few direct human effects, and has escaped (for the most part) the impact of fire suppression policies. Using principal components analysis (PCA), we quantified the variation in stand composition, structure, and diversity and related this variability to current fuel loadings, fire history, and harvesting history. The first PCA axis represented the structural and compositional variation across our dataset associated with the harvesting history of the 50 sampled stands. Stands with a history of harvesting clearly differentiated themselves by high abundance of jack pine and lower structural diversity of the overstory and of the understory vegetation. The second PCA axis revealed a negative correlation between red pine overstory abundance and compositional diversity of the stands, as determined by the Shannon Diversity

Index. The third PCA axis differentiated complex, multi-cohort stands with old (250–300 years) trees in the overstory, which we believe resulted from repeated fires, from younger, less structurally complex stands. Stands which experienced repeated fires showed reduced amounts of fine woody debris and shallower duff depth. No relationship was found between descriptors of fire history and the amount of coarse woody debris (CWD) or litter. CWD increased in multi-cohort stands with high variations in tree diameter, whereas litter depth was higher in both jack pine-dominated, harvested stands and structurally diverse red pine stands and lower in the middle of this gradient. We suggest that fire has a role in restoration programs and sustainable management of red pine-dominated forest ecosystems of this region. For more information see Drobyshev et al. (2008b).

D. Fire and stand dynamics of old-growth mixed-pine forest ecosystems

Our fire history analyses (see above) demonstrate that fire is an important type of natural disturbance in mixed-pine forest ecosystems of SNWR. Both red pine and eastern white pine are adapted to a fire regime characterized by low- to moderate-intensity surface fires occurring every 5–40 years. These fires prepare a mineral seedbed for regeneration and impede the establishment of competing vegetation. In order to examine the age structure and radial growth patterns of old-growth mixed-pine stands, and relate these patterns to all known local fires, we collected a total of 200 radial growth samples from red pine and eastern white pine trees in the Seney Wilderness Area of eastern Upper Michigan. Analyses of samples dated from 1652–2006 suggest that natural fire appears to negatively affect the growth of the surviving pine trees for several years following the fire with several trees showing growth increases that are sustained for five to ten years after a fire. Fires also help promote new pine regeneration. Our increased understanding of these patterns will help land managers design silvicultural systems that emulate the outcomes of natural fire regimes, which will also help restore the structure and function of these once extensive mixed-pine forest ecosystems (some of which are being implemented at SNWR and will be monitored by the research team in the future). For more information see Rist (2008).

E. Songbird assemblages in mixed-pine forest ecosystems

Using the same network of 80 500 m² plots distributed across the SNWR, we surveyed the songbird communities using standard protocols in the summer and fall of 2009. These analyses suggest that songbird assemblages are associated with different stand structures related to past fire history and forest management. In total, we encountered 78 different songbird species in the mixed-pine forest ecosystems at SNWR. More analyses of these data are ongoing, with a focus on comparing how the songbird assemblages of old-growth mixed-pine forest ecosystems differ from those with a history of prescribed fire, harvesting, and plantation management.

F. Resource manager objectives and alternatives to management and restoration

In many regions and across many different types of forest ownership, there is an increasing emphasis on developing a more holistic approach to forest ecosystem management, one that is more focused on emulating the outcomes of natural disturbance patterns. However, the complexity involved in such an approach, both ecologically and socio-economically, presents many decision-making challenges. We utilized a structured decision-making approach aimed at

encouraging more informed management choices. The goal was to identify fundamental management objectives and alternatives for management through open-ended interviews with 13 land managers of mixed-pine forest ecosystems in eastern Upper Michigan. The results indicate that where mixed-pine forest ecosystem management is concerned (including management with a restoration emphasis), ecologically motivated objectives (e.g., restoring ecosystem integrity) take precedence over socio-economically motivated objectives (e.g., providing forest products). The reverse is true for fire management, where socio-economic objectives (e.g., protecting public safety) take precedence over ecological objectives. Despite interest in restoring fire, or using fire as one of many management tools to help emulate natural disturbances, land managers felt their options were limited by uncertainty about the potential risks to their management objectives. They also faced difficult tradeoffs between achieving short- versus long-term objectives, as well as significant external barriers (e.g., institutional mandates). These results highlight the need for decision-support tools that will assist managers in balancing competing objectives and making difficult tradeoffs in highly complex decision contexts. For more information on these analyses and how we translated this information into restoration-based fuel reduction recommendations see Wilson et al. (2009) and Corace et al. (2009).

V. Management Implications

In the previous section we described the major findings of the project which were focused on the new knowledge gained regarding the fire history, forest composition and structure, fuel loadings, songbird assemblages, and the factors that drive the decision-making process of land managers in the eastern Upper Peninsula of Michigan. These findings are described in detail in the variety of deliverables including scientific papers, reports, and website, and are intended for resource managers, policymakers, and scientists of the region (see Appendix for complete list). In this section we explore the implications of our findings for both resource managers and policymakers.

A. Resource managers

The information we developed on the fire regime and its influence on forest composition, structure, and fuel loadings is directly related to current prescribed fire and forest management activities at SNWR and by extension to other areas dominated by mixed-pine forest ecosystems in the Seney Sand Plain ecoregion. These would include forest ecosystems located on the Hiawatha National Forest, Lake Superior State Forest, and TNC's Two-Hearted Forest Reserve located north of Newberry, Michigan.

At SNWR, our findings have been directly influential in the development of a Comprehensive Conservation Plan for Seney NWR (USFWS 2009), especially related to the maintenance and restoration of mixed-pine forest ecosystems. The characteristics of the pre-EuroAmerican fire regime is providing a basis for SNWR managers to design mechanical treatments and prescribed fire plans and refine existing wildland fire use plans already developed. Additionally, our data helps to elucidate how catastrophic fire and then fire suppression efforts affected forest composition, structure, and fuel loadings. This increased understanding of the biological legacies of these activities will aid resource managers with designing fuel reduction and restoration treatments. For example, we have documented that red pine will adequately respond

to release following fire on these sites. As a result, underplanting of red pine following thinning of dense jack pine, or the utilization of mature red pine as seed trees, may be appropriate silvicultural techniques for restoring red pine in these forest ecosystems following mechanical fuel removal. Currently, the research team is working with land managers at SNWR to design monitoring programs of existing and future fuel reduction treatments to test some of these suggested silvicultural treatments.

B. Policymakers

In terms of policymakers, our results show that fuel reduction in these forest ecosystems is an important objective, but is usually a means to some other objective, such as ecosystem restoration or improving wildlife habitat. Additionally, it is clear from our analyses that there is tension between ecologically motivated objectives and socioeconomic objectives when it comes to using prescribed fire or wildfire as a tool to reduce fuel loadings. Consequently, any effort to focus on fuels reduction or management will be best accomplished if tied to another management objective, and there is a clear need for decision-support tools that will assist managers in balancing competing objectives and making difficult tradeoffs in highly complex decision contexts.

The next step in this process is to examine the best available scientific and technical data to characterize the impacts or consequences of the various alternatives on the fundamental or ends objectives. Once the consequences have been established, then a complete decision-support tool can be provided to the various managing authorities to assist in making trade-offs and ultimately more informed management decisions. Such a tool will allow the weighting of various objectives according to their importance to the particular management authority and the calculation of the utility or overall performance of each alternative (see Hammond et al. 1999 for a complete description of this process). The initial findings reported here could also be used as the framework for a more quantitative assessment of knowledge, objectives, perceptions, and preferences in this context. For example, the results of these initial interviews could be further quantified through a follow-up representative national survey of management personnel involved in mixed-pine management in order to further expand the applicability of these findings to forest ecosystems beyond eastern Upper Michigan.

VI. Relationship to Other Recent Findings and Ongoing Work on This Topic

Members of this research are currently involved with a number of projects related to this project. These include:

- 1) *Fuels treatment guide for mixed-pine forest ecosystems of the northern Lake States. (JFSP Project 09-2-01-22)* This effort funded by JFSP is the next step building off of this research. Using the decision-support tool developed from our detailed interviews, we are developing a fuels treatment guide that addresses the effects of potential fuel reduction treatments on the ecology, wildlife, and management of mixed-pine forest ecosystems of eastern Upper Michigan and the landscape of the northern Lake States.

- 2) *Fire science consortium for the northern Lake States. (JFSP Project 09-4-1-11).* With funding from JFSP, the research team is working to develop a full proposal to coordinate and administer a fire science consortium for fire-dependent ecosystems of the northern Lake States.
- 3) *Ecology and management of jack pine forest ecosystems for the endangered neotropical migrant Kirtland's warbler.* Related to these efforts, members of the research team are examining the role of forest management activities in jack pine forest ecosystems of northern Lower Michigan. This research has been funded to date by the USFWS, and is closely related to the overall goal of designing more ecologically appropriate forest management activities for fire-dependent pine ecosystems of the northern Lake States. Additionally, a related proposal is pending to the JFSP program RFA 10-1 Task 06.

VII. Future Work Needed

The efforts listed above in Part IV outline the activities of the research team on projects directly related to the results included in this report. In addition to these efforts, the research team is exploring other potential opportunities to build upon the research outlined here. These efforts include:

How effective are specific restoration-based fuel reduction techniques with respect to reducing fuels and restoring ecosystem structure and function?

The research team is exploring opportunities with the U.S. Fish and Wildlife Service to implement long-term demonstration sites and studies to examine the effectiveness of different restoration-based fuel treatments. For example, the research team is looking to partner with SNWR to help design a study to examine these treatments via a pending timber sale in an altered mixed-pine forest ecosystem at SNWR.

How important and what effects does natural and prescribed fire have on other fire-dependent forest ecosystems of the northern Lake States, including jack pine forest ecosystems (including barrens), black spruce peatland ecosystems, and coastal pine forest ecosystems?

The research team is exploring opportunities to examine these questions in other fire-dependent ecosystems through new partnerships with the U.S. Forest Service and U.S. Fish and Wildlife Service. Proposals are being submitted to the JFSP program and NSF programs, as well as internal University programs, to fund these efforts.

How variable is the role of fire as a disturbance agent in red pine dominated ecosystems across its native range?

The research team is exploring opportunities to work with other researchers across the northern Lake States and adjacent Canada to examine this variability. Field visits to red pine forest ecosystems across the range have already occurred and funding sources are being identified.

VIII. Deliverables Cross-Walk

Proposed	Delivered	Status
Project website	http://www.pinerestoration.org	Updated as needed
GIS coverages	GIS coverages	Completed
Study of mixed-pine forest ecosystem fuel loadings, forest composition, and structure	(1) Drobyshv et al. 2008. Forest Ecology and Management 256:1723-1733. (2) Rist. M.S. Thesis (3) Rist et al. (manuscript). Radial growth of red pine and fire. (4) Goebel et al. (manuscript). Landform influences on fuel loadings	(1) Completed (2) Completed (3) In Review (3) In progress
Study of mixed-pine fire history	(1) Drobyshv et al. 2008. Canadian Journal of Forest Research 38:2497-2514. (2) Goebel et al. (manuscript). Fire history sampling.	(1) Completed (2) In progress
Study of bird assemblages ¹	(1) Corace et al. (manuscript). Bird assemblages of mixed-pine forest ecosystems	(1) In progress
Guide to restoration-based fuel reduction	(1) Wilson et al. 2009. Ecological Restoration (2) Corace et al. 2009. Forestry Chronicle (3) Corace and Goebel 2010. (4) Goebel et al. (manuscript). Fuel reduction and restoration guide	(1) Completed (2) Completed (3) Completed (4) In progress
Visualization Package	(1) Posters for SNWR Visitor Center (2) Streaming video of research results	(1) Completed (2) In progress

¹Research associated with bird assemblages added to initial project during extension in 2009.

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X. Additional Reporting

Appendices and other inputs to JFSP.

A. Inputs into Findings Database

Available from www.firescience.gov.

B. Digital Photo Library

Photos available on CD at request.

C. Completed Deliverables

Available on CD, project website, and entered into citation database at www.firescience.gov.

D. Deliverables Citation Database

Items entered into JFSP Citation Database through February 15, 2010.

Final Report

Goebel, P.C., D.M. Hix, R.S. Wilson, and R.G. Corace, III. 2010. Restoration-Based Fuel Reduction Recommendations for Mixed-Pine Forests of Upper Michigan. Final Project Report (JFSP Project Number 05-2-1-86). February 15, 2010. Wooster, OH.

Websites

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Knowledge Transfer Workshops and Advisory Meetings

Drobyshev, I., and R.G. Corace, III. 2006. *Fire disturbance in boreal forests and project activities for the staff and volunteers of the Seney NWR*. August 2006, Seney, MI.

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Corace, R.G. III, P.C. Goebel, D.M. Hix, and I.V. Drobyshev. Disturbance regimes in relations to forest management at Seney National Wildlife Refuge. Training session for USFWS National Wildlife Refuge System biologists. Seney National Wildlife Refuge, Seney, Michigan. October 18, 2007.

Corace, R.G., III. 2009. *Update of restoration-based fuel reduction project*. Great Lakes Biology Network Forest Ecology and Management Meeting, September 15-17, 2009. Seney National Wildlife Refuge, Seney, MI.

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Corace, R.G., III. *Forest ecology and management workshop, with an emphasis on ecological forestry*. Workshop for National Wildlife Refuge System Biologists from AR, MN, WI, MI, OH, GA, ME, and VT (USFWS Regions 3,4,5), September 11-15, 2009. Seney National Wildlife Refuge, Seney, MI.

Professional Presentations and Invited Talks

Corace, R. G., III. 2006. A coarse-filter approach to forest management: Seney NWR. USFWS Region 3/5 Forest Management Workshop, Big Oaks National Wildlife Refuge, Madison, IN.

Corace, R.G., III and P.C. Goebel. 2006. Forest ecosystem restoration in the context of migratory bird conservation at Kirtland's Warbler Wildlife Management Area and Seney National Wildlife Refuge. Poster, USFWS Region 3 Biological Workshop, La Crosse, WI.

Drobyshev, I., P.C. Goebel, D.M. Hix, R.G. Corace, III, and M.E. Semko-Duncan. 2007. *Fire history of red pine-dominated forests of Seney National Wildlife Refuge, Upper Michigan*. 2nd Fire Behavior and Fuels Conference, March 26-30, 2007. Destin, FL.

Drobyshev, I., P.C. Goebel, D.M. Hix, M.E. Semko-Duncan, and R.G. Corace, III. 2007. *Interactions between fire disturbance and forest structure: a case study of red pine-dominated forests of Seney National Wildlife Refuge, Upper Michigan*. 6th North American Forest Ecology Workshop, June 18-22, 2007. Vancouver, BC, Canada.

Drobyshev, I., P.C. Goebel, D.M. Hix, R.G. Corace, III, and M.E. Semko Duncan. 2007. *Fire history of red pine-dominated forests of Seney National Wildlife Refuge, Upper Michigan*. October 9-12, 2007. 34th Natural Areas Conference, Cleveland, OH.

Goebel, P. C., D.M. Hix, I. Drobyshev, R.G. Corace, III, R.S. Wilson, and B.J. Palik. 2007. *Restoration-based fuel reduction recommendations for mixed-pine forests of upper Michigan*. 2007 Society of American Foresters National Convention, October 23-27, 2007. Portland, OR.

- Rist, S. G., P.C., D.M. Hix, and R.G. Corace, III. 2007. *Historical forest management on national wildlife refuges: a case study*. 2007 Society of American Foresters National Convention, October 23-27, 2007. Portland, OR.
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- Corace, R. G., III, P.C. Goebel, and N.C. Seefelt. 2008. *Forest ecosystem conservation and restoration: Seney National Wildlife Refuge and Kirtland's Warbler Wildlife Management Area*. 6th Annual Western Great Lakes Research Conference, April 1-2, 2008. Marquette, MI.
- Hix, D.M., P.C. Goebel, R.S. Wilson, I. Drobyshev, and R.G. Corace, III. 2008. *Using fire history, vegetation, and risk analyses to develop integrated strategies for mixed-pine forest restoration in Upper Michigan*. 93rd Annual Meeting of the Ecological Society of America, August 3-8, 2008. Milwaukee, WI.
- Rist, S.G., P.C. Goebel, and D.M. Hix. 2008. *Radial growth response in old-growth mixed-pine ecosystems of Upper Michigan*. 2008 SAF National Convention, November 5-9, 2008. Reno, NV.
- Corace, R.G., III. 2009. *Conservation filters and ecological forestry on National Wildlife Refuges*. School of Environment and Natural Resources, The Ohio State University Seminar Series. Columbus, OH.
- Wilson, R.S., D.M. Hix, P.C. Goebel, and R.G. Corace, III. 2009. *Identifying land manager objectives and alternatives for mixed-pine forest ecosystem management and restoration in eastern Upper Michigan*. 2009 Midwest Jack Pine Symposium, August 25-26, 2009. Olanah, WI.
- Goebel, P.C., D.M. Hix, R.S. Wilson, and R.G. Corace, III. 2009. *Linking ecological and structured decision-making networks to develop local- and landscape-scale restoration strategies for mixed-pine forests of Upper Michigan, USA*. 16th Annual Conference of the International Association of Landscape Ecology (UK Chapter), September 1-3, 2009. Edinburgh, Scotland, UK.
- Goebel, P.C. 2009. A requiem or renaissance for mixed-pine forest ecosystems in the northern Lake States of the USA? Invited presentation. Environmental Research Institute. September 4, 2009. Thurso, UK.
- Goebel, P.C., D.M. Hix, R.G. Corace, III, and R.S. Wilson. (presentation). *Restoration-based fuel reduction recommendations for mixed-pine forests of Upper Michigan*. 4th International Fire Ecology and Management Congress, November 30 - December 4, 2009. Savannah, Georgia.

Graduate Education

Rist, Stephen G. 2008. Legacies of forest management and fire in mixed-pine forest ecosystems of the Seney National Wildlife Refuge, eastern Upper Michigan. M.S. Thesis, School of Environment and Natural Resources, The Ohio State University, Columbus, OH (P. Charles Goebel and David M. Hix, co-advisors).

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Corace, R.G., III, P.C.Goebel, and N.E. Seefelt. 2008. Innovative forest management: Seney National Wildlife Refuge and Kirtland's Warbler Wildlife Management Area. *Forest Wisdom*. Spring. Pp. 4, 8.

Drobyshev, I.V., Goebel, P.C., Hix, D.M., Corace III, R.G., and Semko Duncan, M. E. 2008. Fire history of red pine-dominated forest ecosystems of the Seney National Wildlife Refuge, Upper Michigan. *Canadian Journal of Forest Research*. 38:2497-2514.

Drobyshev, I.V., Goebel, P.C., Hix, D.M., Corace III, R.G., and Semko Duncan, M.E. 2008. Interactions between forest structure, fuel loadings and fire history: a case study of red pine-dominated forests of Seney National Wildlife Refuge, Upper Michigan. *Forest Ecology and Management*. 256:1723-1733.

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Corace, R. G., III, and P.C. Goebel. 2010. An ecological approach to forest management for wildlife: integrating disturbance ecology patterns into silvicultural treatments. *The Wildlife Professional*. Spring:38-40. *Invited paper*.

Brosfokske, K.D., and D.T. Cleland. 2010. Historical Ecosystems of Schoolcraft County, Michigan: A Reconstruction of Vegetation, Structure, and Disturbance Regimes from the Original General Land Office Survey Notes. Final report. Rhinelander, WI. Available online at www.pinerestoration.org.

Publications under Review

Rist, S. G., P.C. Goebel, D.M. Hix, I. Drobyshev, and R.G. Corace, III. Age structure and radial growth response of old-growth mixed-pine stands following fire in Upper Michigan. *Forest Science*. (Manuscript under revision)

Deliverables in Preparation

Goebel, P.C., D.M. Hix, R.G. Corace, III, et al. (manuscript). Landform and management influences on forest fuel loadings. *Canadian Journal of Forest Research*.

Goebel, P.C., D.M. Hix, R.G. Corace, III, et al. (manuscript). Impacts of wedge sampling for fire history studies. *Tree Ring Research*.

Corace, R.G., III, P.C. Goebel, and D.L. McCormick. (manuscript). Bird assemblages associated with mixed-pine forest ecosystems. *Forest Ecology and Management*.

Goebel, P.C., D.M. Hix, R.G. Corace, III, and R.S. Wilson. (report). Restoration-based fuel reduction recommendations for mixed-pine forests of Upper Michigan. *U.S. Fish and Wildlife Service Research Bulletin*.

Goebel, P.C., R.G. Corace, III, D.M. Hix, and R.S. Wilson. (webinar). *Restoration-based fuel reduction methods for mixed-pine forest ecosystems workshop*. March 2010, Seney, MI.

Goebel, P.C., R.G. Corace, III, D.M. Hix, and R.S. Wilson. (video). *Summary of findings: Restoration-based fuel reduction methods for mixed-pine forest ecosystems*. March 2010, Wooster, OH.

Corace, R.G., III, P.C. Goebel, P.C., D.M. Hix, and R.S. Wilson. (field tour). *Restoration-based fuel reduction methods for mixed-pine forest ecosystems workshop*. July 2010, Seney, MI.