RESEARCH REPORT

Identifying Land Manager Objectives and Alternatives for Mixed-Pine Forest Ecosystem Management and Restoration in Eastern Upper Michigan

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ABSTRACT

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 socioeconomically, presents many decisionmaking challenges. This study was a first step in a structured decisionmaking 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 such as restoring ecosystem integrity take precedence over socioeconomically motivated objectives like providing forest products. The reverse is true for fire management, where socioeconomic objectives like 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 trade-offs between achieving short- versus long-term objectives, as well as significant external barriers such as institutional mandates. These results highlight the need for decision-support tools that will assist managers in balancing competing objectives and making difficult trade-offs in highly complex decision contexts.

Keywords: decisionmaking, fire, mixed pines, restoration, risk management

Introduction

The composition and structure of many forests across the northern Great Lakes states have changed considerably over the past 200 years (Schulte et al. 2007). Prior to European settlement, multicohort red pine (*Pinus resinosa*) and eastern white pine (*P. strobus*) forests dominated many portions of these northern lake states and were generally maintained by periodic surface fires (Whitney 1986, Cleland et al. 2004, Drobyshev et al. 2008a, 2008b). However, owing to extensive high-grading (selective cutting of only the largest and best trees) and clear-cutting, the secondary consequences of such practices (catastrophic slash fires, for example) and subsequent fire suppression efforts, these mixed-pine forest ecosystems have changed profoundly (Drobyshev et al. 2008a) (Figure 1). Multiple land management agencies have the stated objective of restoring mixed-pine forest ecosystems. For example, managers in the Seney National Wildlife Refuge state that their specific focus is to reestablish degraded components of these ecosystems and promote resiliency to future disturbances (Corace et al. 2008). The Michigan Department of Natural Resources Red Pine Project aims to restore natural red pine dominated forests on some state lands in order to attain desired ecological characteristics while continuing traditional silvicultural practices in plantation settings to achieve economic objectives (Pilon 2006).

The restoration of mixed-pine forests across the northern Great Lakes states is challenging because these ecosystems are believed to be compositionally and structurally more complex than their plantation counterparts. This complexity is largely in response to frequent surface fires and less frequent crown fires in natural mixed-pine ecosystems (Palik and Zasada 2003, Gilmore and Palik 2006). In eastern Upper Michigan, Drobyshev and others (2008b) found that low-intensity surface fires were the dominant disturbance regulating

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Figure 1. Dense jack pine (*Pinus banksiana*) stand (a) that has developed on a former mixed-pine site contrasted with an old-growth mixed-pine stand (b) that has experienced frequent low-intensity surface fires. Photos by R. Gregory Corace III

the development of mixed-pine forest ecosystems. However, research from other portions of the range (such as Minnesota and Ontario) suggests that large, stand-replacing fires were historically the primary mode of stand development in mixed-pine forest ecosystems (Heinselman 1973, Bergeron and Brisson 1990). This conflicting evidence suggests that geographic variability exists in the primary mechanisms by which these pine species regenerate and establish and in the way these forests develop structurally and compositionally. As a result, many managers have been frustrated in attempts to promote the natural regeneration of mixed-pine forest ecosystems through prescribed fire and other management techniques (Gilmore and Palik 2006).

Successful restoration may require a more diverse approach to mixed-pine forest management in order to emulate patterns resulting from natural disturbances (e.g., pests, drought, wildfire, and windstorms) and produce important structural outcomes, such as multi-cohort stands and snags that are essential for many wildlife species (Corace et al. forthcoming) (Figure 2). This more diverse approach would incorporate multiple management techniques while tailoring activities to site-specific edaphic, physiographic, and disturbance conditions. Developing such an approach introduces complexity into the decision process that can be problematic for managers. Previous studies suggest that forest managers often make excessively risk-averse management decisions that do not address their key management objectives (Christensen 2003, Stankey et al. 2003). Maguire and Albright (2005) propose that these risk-averse decisions occur because of the tendency of managers to use decision heuristics, or shortcuts, when dealing with complex decisions. One such shortcut is that people tend to overweight short-term risk and discount long-term risk in order to simplify the decision. An overreliance on these simplifying decision rules may result in choices that do not address fundamental management objectives. Arvai and colleagues (2006) highlight the need for tools that improve the decisionmaking process and ensure that a chosen management option maximizes achievement of the stated objectives as opposed to reflecting a potentially inappropriate decision rule or heuristic.

A Structured Decision Making Approach

Structured decisionmaking (SDM) is one such tool designed to encourage the consideration of multiple objectives as well as facilitate trade-offs when these objectives conflict (National Research Council 1996). Structured decisionmaking combines technical expertise and rational decisionmaking into a process that ensures that the resulting decisions will achieve greater public support and success over the long term. There are five basic steps common to SDM approaches (Hammond et al. 1999, Gregory 2000):

1. Characterizing objectives that matter most to participants.
2. Creating a set of alternatives that address these objectives.
3. Employing the best available technical information to characterize possible impacts of alternatives on stated objectives.
4. Identifying and addressing trade-offs based on the values and objectives of the participants.
5. Summarizing areas of agreement and disagreement in order to choose the

Figure 2. Red pine (*Pinus resinosa*) provides wildlife habitat in Seney National Wildlife Refuge: a) red squirrel (*Tamiasciurus hudsonicus*) in a red pine cavity; b) black bear (*Ursus americanus*) cub in an old-growth red-pine. Photos by Igor Drobyshev (a) and R. Gregory Corace III (b)

option that best meets the needs and objectives of the decisionmakers.

The research presented here addresses Steps 1 and 2 for the specific context of mixed-pine forest ecosystem management in eastern Upper Michigan. We worked to identify objectives and management strategies that land managers consider when making decisions about mixed-pine forests. These findings were then organized into a means-ends network, which separates fundamental or "ends" management objectives from "means" objectives and highlights the causal influences between them. Ends objectives are essential to achieving agency mandates, while means objectives are simply potential paths or alternatives that may help achieve a particular ends objective. Our larger research goal is to integrate this input from regional experts in mixed-pine forest ecosystems with ongoing ecological research (Step 3) in order to develop a decision support tool that will assist managers with making future management decisions (Steps 4 and 5). Ecological research being conducted in parallel with the study reported here is clarifying the importance of site-specific characteristics, evaluating the effectiveness of various management techniques, and demonstrating the importance of fire for restoring and maintaining mixed-pine ecosystems (Drobyshev et al. 2008a, 2008b, Corace et al. forthcoming).

Many previous studies of decision-making in the context of forest and fire management have focused on public perceptions of the risk and the factors influencing the management decision (Zaksek and Arvai 2004, Absher and Vaske 2007, Bright et al. 2007, Bowker et al. 2008). Fewer studies have attempted to assess the objectives, perceptions, and knowledge of land managers and translate these findings into a useful tool for future management decisions. Existing decision support studies have focused generally on managing fire risks in forests but have not incorporated fire as only one practice in a suite of tools available for general management or a specific restoration effort (Ohlson et al. 2006, Bonazountas et al. 2007, Hessburg et al. 2007, Kaloudis et al. 2008).

Methodology

We recruited 13 land managers to participate in the project from the following: the United States Department of Interior Fish and Wildlife Service (USFWS) (n = 5), the United States Department of Agriculture Forest Service (USFS) (n = 3), The Nature Conservancy (TNC) (n = 3), and the Michigan Department of Natural Resources (MDNR) (n = 2). A larger number of USFWS interviewees were recruited owing to the large role that USFWS plays in the management, and in particular the restoration, of these mixed-pine ecosystems. The interviewees have direct management authority in mixed-pines forest ecosystems (they have discretion to implement on-the-ground practices that affect ecosystem composition and structure) and represent agencies or organizations with different but often overlapping mandates (Table 1).

Each land manager was interviewed for one to two hours, and all were 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 terms (not reported here), 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

Table 1. The mission statements of the four managing agencies and organizations chosen for participation in this study.

Management Authority	Mission Statement
USFWS National Wildlife Refuge System	To administer a national network of lands and waters for the conservation, management, and, where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans.
The Nature Conservancy	To preserve the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive.
USDA Forest Service	To sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations.
Michigan Department of Natural Resources	Committed to the conservation, protection, management, use and enjoyment of the State's natural resources for current and future generations

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.

Each individual interview was audiotaped and transcribed and the content coded by the lead author. Initial codes were developed from a review of the literature and then synthesized with major themes that appeared across the responses to create a final coding scheme. This final set of concepts was used to categorize each response given by a particular participant. For each concept the participant was assigned either 1 for mentioning that concept, or 0 for not mentioning it. A research assistant validated this coding procedure by recoding 20% of the original sample. The recoding of the subsample achieved the minimum level of intercoder reliability (80%) recommended for measures based on percent agreement (Lombard et al. 2002).

The analysis is restricted to the frequency of response across the various agencies or organizations for each of the individual coded concepts (total number of 1 codes divided by total number of participants). The specific concepts were organized by overarching categories that reflect the types of questions asked during the interview. These categories are forest management objectives, historic role of fire, perceived risks and benefits of fire in the ecosystem, objectives for managing fire, available management actions, perceived risks and benefits of current management actions, and desired future management actions.

Results and Discussion

Forest Management Objectives

Ecologically motivated objectives took precedence over socioeconomically motivated objectives for general forest management. The top three general forest management objectives, in rank order, were to promote wildlife diversity, promote habitat diversity, and manage and coordinate across landscapes (Table 2). The top socioeconomic objective was to provide timber or other forest products. It is interesting to note that approximately half of the interviewees mentioned landscape-scale management and coordination as a general forest management objective. There is a clear split among the respondents in terms of the importance of taking a landscape-scale approach to management, and without agreement between managing authorities on this point, this particular forest management objective will not be successfully achieved, given that multiple authorities often exist within a particular landscape unit.

After discussing general forest management objectives, participants were asked for management objectives specific to mixed-pine forest ecosystems. Overall, most objectives identified were ecologically motivated. Those mentioned most often were restoring mixed-pine ecosystems, promoting heterogeneous and multisuccessional composition and structure, and protecting late-successional and rare ecosystems (Table 2). In general, respondents struggled to define the ideal composition and structure for mixed-pine forest ecosystems because of the importance of so many site-specific factors, such as disturbance, proximity to human settlement, soil type, or temporal reference point. This is an encouraging result, as recent research has shown that mixed-pine forest ecosystem management, and in particular management with a restoration focus, should be site-specific and account for ecoregionally specific physiographic, edaphic, and disturbance conditions (Gilmore and Palik 2006, Drobyshev et al. 2008a, 2008b).

Historic Role of Fire

Over 75% of respondents believed that fire was a major disturbance that shaped many forest types and maintained these ecosystems over time. In particular, fire was believed to be important for shaping and maintaining marshlands, jack pine (*Pinus banksiana*) stands, and mixed-pine forest ecosystems. The strong agreement among respondents regarding the role of fire as a necessary disturbance in mixed-pine forest ecosystems illustrates why ecological knowledge about a forest ecosystem does not necessarily dictate future management. Despite this understanding of the importance of fire historically, it was still a challenge for many land managers in this

Table 2. The top individual objectives (mentioned by over 20% of respondents) for general forest (GF) and specific mixed-pine forest (MPF, shaded rows) management listed in descending order by percent agreement. The four participating institutions are listed separately to show percent agreement within each.

Subcontent Area	Forest Management Objective	Percent Agreement Total n = 13	USFWS n = 5	TNC n = 3	USFS n = 3	MDNR n = 2
Ecological (GF)	Promote wildlife diversity	**77**	100	67	67	50
Ecological (GF)	Promote habitat diversity/snag density	**69**	100	33	67	50
Ecological (MPF)	Restore mixed-pine ecosystems	**69**	80	100	67	0
Ecological (MPF)	Promote heterogeneous/multisuccessional comp/structure	**69**	100	67	33	50
Ecological (MPF)	Protect ecological maturity/rare ecosystems	**46**	60	67	33	0
Ecological (GF)	Manage and coordinate across landscapes	**46**	60	67	33	0
Ecological (GF)	Maintain openings	**38**	40	33	33	50
Societal (GF)	Provide timber/forest products	**38**	20	0	67	100
Societal (GF)	Allow for multiple use/maximize potential	**31**	40	0	67	0
Ecological (GF)	Protect/restore ecosystem integrity/resilience	**31**	40	0	33	50
Ecological (MPF)	Manage for disturbance dependent composition/structure	**31**	20	0	33	100
Societal (MPF)	Manage differently in the interface vs. interior	**23**	40	0	33	0

study to incorporate fire in current forest management (see "Desired Future Management Actions," where the most common response for future action was more fire use). This further validates the need for tools that will help land managers deal with the difficult short- versus long-term trade-offs required by fire use and prescription. Such action may require some risk to socioeconomic objectives in the short-term while promoting ecological objectives in the long-term, or vice versa.

Also, 31% of respondents believed that naturally occurring surface fires were historically more common than crown fires. They believed that these surface fires served the purpose of reducing fuels or biomass. This belief is consistent with recent research on the fire regimes of eastern Upper Michigan (published after these interviews) (Drobyshev et al. 2008b). Future communications between scientists and managers should therefore emphasize this finding to ensure that such knowledge informs management decisions.

Perceived Risks and Benefits of Fire in the Ecosystem

In general, respondents were more concerned about the risks posed by the use of fire to socioeconomic management objectives than to ecological objectives. A clear majority (greater than 75% of respondents) was concerned about risks posed to human health and life, timber products, and other property, while no ecological concern (such as impacts on soil structure, wildlife and habitat, and water quality) was mentioned by a majority of respondents (Table 3). This high level of concern about risks to society and the economy may lead to more risk-averse management decisions (i.e., fire suppression). Previous research from judgment and decision making indicates that activities or technologies judged as high risk are automatically perceived to be of low benefit (Alhakami and Slovic 1994). For example, if wildland fire use (WFU) is perceived as posing a high level of risk to an objective of interest (e.g., protecting human health), it is difficult to accurately recognize the benefits that are relevant to another fundamental objective (e.g., promoting wildlife habitat). WFU is then framed as a risky choice, and the probability of a negative outcome resulting from WFU is often overestimated (Maguire and Albright 2005).

The benefits of fire were mentioned more equally between socioeconomic and ecological objectives. The majority of respondents mentioned socioeconomic benefits related to the creation of jobs and general stimulation to the local economy, as well as increased opportunities for nonconsumptive recreation like bird-watching and hiking. A similar majority of respondents mentioned ecological benefits related to the creation of habitat for wildlife and the regeneration and maintenance of early successional species (Table 4).

Several objectives were mentioned as both being at-risk from fire and potentially benefiting from fire. This dichotomy often reflected the short-term versus long-term risk trade-off that may be required when using fire as a management tool. For example, respondents believed that nonconsumptive recreation would likely benefit from fire in both the short and long term because of increased recreational opportunities. However, respondents also mentioned that nonconsumptive recreation could potentially be at risk in the short term owing to limited or decreased recreational opportunities. On a related note, wildlife and their habitat were believed to be largely at risk from fire in the short term but more likely to benefit over the long term. Finally, respondents believed that jobs and economic growth would be exposed to a certain degree of risk in the short term but would perhaps be more likely to benefit from fire over the long term. These responses highlight the complexity that exists regarding

Table 3. The top perceived risks associated with fire management (mentioned by over 20% of respondents) listed in descending order by percent agreement. The four participating institutions are listed separately to show percent agreement within each.

		Percent Agreement				
Subcontent Area	**Perceived Risk**	**Total** *n* **= 13**	**USFWS** *n* **= 5**	**TNC** *n* **= 3**	**USFS** *n* **=3**	**MDNR** *n* **= 2**
Societal	Loss of human health/life	**85**	100	67	67	100
Societal	Decreased timber products	**77**	60	100	67	100
Societal	Damaged property/structures	**77**	40	100	40	100
Societal/Ecological	Further degradation from catastrophic fire	**46**	80	0	33	50
Societal	Negative public reactions/perceptions	**38**	20	67	33	50
Ecological	Damaged soil structure	**38**	20	33	67	50
Ecological	Loss of wildlife and habitat	**38**	40	67	0	50
Ecological	Loss of water quality/fisheries/hydrology	**31**	20	33	33	50
Societal	Decreased recreation/tourism (aesthetics)	**31**	20	33	0	100
Societal	Loss of jobs/economy	**31**	40	33	33	0
Societal	Travel/traffic impacted (due to air quality)	**23**	0	0	0	50
Societal	Increased cost	**23**	20	33	0	0
Societal/Ecological	Increased chance of unintended consequences	**23**	20	67	0	0

Table 4. The top perceived benefits associated with fire management (mentioned by over 20% of respondents) listed in descending order by percent agreement. The four participating institutions are listed separately to show percent agreement within each.

		Percent Agreement				
Subcontent Area	**Perceived Benefit**	**Total** *n* **= 13**	**USFWS** *n* **= 5**	**TNC** *n* **= 3**	**USFS** *n* **=3**	**MDNR** *n* **= 2**
Ecological	Increased wildlife/habitat	**77**	80	100	67	50
Societal	Job creation/economic growth	**69**	100	33	67	50
Ecological	Regeneration/early succession promoted	**62**	80	33	33	100
Societal	Increased nonconsumptive recreation	**54**	40	67	67	50
Societal/Ecological	Best, most cost-effective tool	**47**	20	67	33	50
Societal	Increased consumptive recreation	**38**	40	33	33	50
Ecological	Healthy, diverse, resilient forests promoted	**38**	40	100	0	0
Societal	Fire as a management tool	**31**	40	0	67	0
Ecological	Site preparation/increased soil nutrients	**31**	40	33	0	50
Ecological	Ecosystems and openings maintained	**31**	0	33	33	50
Societal	Increased forest products	**23**	20	33	0	50
Societal/Ecological	Less catastrophic fire/more fuels reduction	**23**	0	100	0	0
Ecological	Invasive species controlled	**23**	20	33	33	0
Ecological	Pests/disease controlled	**23**	0	67	33	0

potential risks and benefits that result from management actions and the importance of considering risks and benefits across time.

Objectives for Managing Fire

When asked about the objectives for managing fire, respondents mentioned socioeconomic objectives more often than ecological objectives. This was the reverse of the response to our question about forest management where ecological objectives took precedence. The top three socioeconomic objectives, in rank order, were meeting a variety of public desires, protecting property, and protecting lives (Table 5). The top three ecological objectives, in rank order, were maintaining biodiversity and habitat, promoting regeneration, and promoting ecosystem health, structure, and resilience. A primary concern of respondents that is both socioeconomically and ecologically driven was to reduce fuel loads and thereby prevent catastrophic fire (mentioned by 62% of respondents overall).

Respondents also mentioned several objectives for the actual practice of managing fire. The majority of respondents mentioned managing differently in the wildland-urban interface than in wildlands, using suppression to reduce short-term risk to socioeconomic objectives, allowing natural fire to play a role, and restoring fire to the ecosystem in order to reduce long-term risk to both socioeconomic and ecological objectives (Table 5). There is an obvious conflict between actions that promote short-term versus

Table 5. The top individual objectives for fire management (mentioned by over 20% of respondents) listed in descending order by percent agreement. The four participating institutions are listed separately to show percent agreement within each.

Subcontent Area	Fire Management Objective	Percent Agreement Total *n* = 13	Total *n* = 5	Total *n* = 3	Total *n* = 3	Total *n* = 2
Practice	Be site specific	**85**	80	100	67	100
Practice	Reduce short-term risk/suppress fire	**77**	80	100	33	100
Societal	Meet public desires	**69**	60	67	67	100
Societal	Protect property	**69**	40	67	100	50
Practice	Allow natural fire to play a role	**62**	100	67	0	50
Societal & Ecological	Prevent catastrophic fire	**62**	80	67	67	0
Practice	Reduce long-term risk/restore fire	**54**	60	67	33	50
Societal	Protect public safety	**46**	60	0	67	50
Ecological	Promote biodiversity/habitat	**46**	40	67	33	50
Ecological	Promote forest regeneration	**38**	0	67	67	50
Societal	Educate the public	**31**	40	33	0	50
Societal/Ecological	Minimize unintended consequences	**31**	40	33	33	0
Ecological	Promote ecosystem health/resilience	**31**	40	33	33	0
Ecological	Maintain healthy ecosystems	**31**	20	33	67	0
Practice	Minimize cost/liabilities	**23**	20	33	0	50
Practice	Prescribe fire	**23**	40	0	0	50
Ecological	Restore forests	**23**	20	33	33	0
Societal	Protect travel/recreation	**23**	40	0	0	50
Societal	Provide forest products	**23**	0	33	33	50

long-term risk reduction, as pursuing both fire restoration and suppression implies a necessary trade-off between action that may pose some increase in short-term risk in order to minimize long-term risk, and action that may minimize short-term risk while posing some increase in long-term risk.

Available Management Action and Related Risks and Benefits

Although there were more techniques mentioned that did not directly incorporate fire (suppression, mechanical thinning, partial harvesting, and planting/seeding) than those incorporating fire (prescribed burning and allowing wildfire to burn through wildland fire use, WFU), using fire as a potential management tool was still a common response. Just as socioeconomic objectives were given priority in fire-management decisions, these same objectives may explain the support for wildfire suppression (mentioned by 62% of respondents) despite an interest in incorporating fire into management plans (prescribed fire mentioned by 85% of respondents and wildland fire use mentioned by 54%).

In general, there was little agreement among participants on whether current management action posed a risk or a benefit to objectives of interest. The majority of these conflicting risk-benefit statements again relate to the short- versus long-term trade-off required by forest- and fire-management decisions and the uncertainty associated with the decision. For example, in the short term, incorporating use or prescription of fire may place biodiversity at risk owing to the potential for the fire to burn out of control (mentioned by approximately 30% of respondents), whereas if the fire burns as intended, it may benefit biodiversity in the long term by maintaining a more sustainable system (mentioned by approximately 60% of respondents). Similarly, respondents mentioned that timber and forest products might benefit from a lack of fire in management owing to less risk of losing valuable trees in the short term (mentioned by approximately 60% of respondents). However, respondents also indicated that valuable trees might be at risk owing to a lack of fire because of the increased probability of catastrophic fire in the future (mentioned by approximately 50% of respondents).

The greatest agreement among respondents in regard to risks created by management action was the unintended consequences created by current management action (for example, the loss of options and flexibility in the future). Approximately 60% of respondents mentioned this concern as a threat to both socioeconomic and ecological objectives and a concern over both the short and long term depending on the specific management action. The relatively low agreement among respondents about the consequences of action demonstrated by the conflicting risk-benefit perceptions mentioned previously, and the relatively high concern about unintended consequences, demonstrates that there is a degree of uncertainty around how management action may impact various objectives of interest.

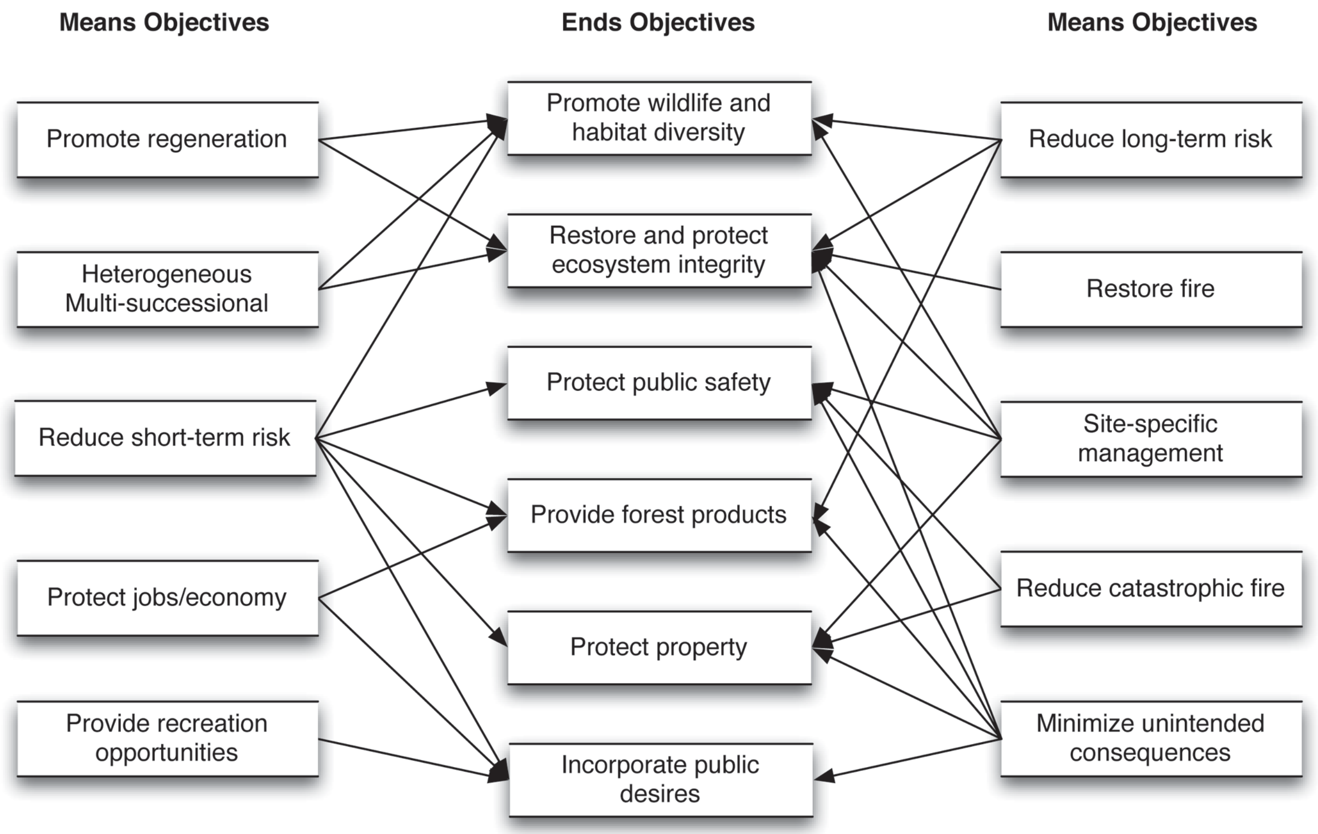

Figure 3. The means-ends network for mixed-pine ecosystem management and restoration. The six fundamental or ends management objectives are shown in the center box. Means objectives, many of which reflect management actions that could be taken to achieve a fundamental objective, are shown on the sides. Arrows denote influences from means to ends mentioned by respondents (for example, promoting regeneration is one means to promoting wildlife and habitat diversity and restoring and protecting ecosystem integrity). All objectives in the network were those mentioned by a majority of respondents.

Desired Future Management Actions

A majority of respondents (approximately 62%) stated that the most desired change in management was to incorporate more WFU and prescribed fire, which could include reestablishing historic fire return intervals. The key barriers that a majority of respondents believed would prevent their taking different actions in the future were, in rank order, mandates and statutes, uncertainty and lack of ecosystem knowledge, lack of resources, public perceptions and needs, and wildland-urban interface constraints. Many of the respondents felt that these barriers were outside their personal control yet have a large impact on how their management decisions and actions are carried out. Although this may be true for some barriers, the development of better decision support tools (for example, fuel management guides) could assist land managers in addressing uncertainty in ecosystem knowledge, as well as public needs.

The desire of land managers to incorporate prescribed natural fire or WFU for resource benefits in eastern Upper Michigan is consistent with a growing trend in fire management across the United States (Van Wagtendonk 2007). In the western United States and a growing portion of the Southeast, lightning-caused fires are being allowed to burn naturally rather than being extinguished. Managers do, however, attempt to "manage" or dictate aspects of these natural fires to accomplish ecological and fuel reduction objectives while protecting people, property, and key resources. While WFU has been applied primarily to federal Wilderness Areas, it is increasingly being considered for lands with nonwilderness objectives, including forests managed for wildlife, timber, watershed, and recreation purposes. While more research is needed for mixed-pine forest ecosystems of the northern Great Lakes states, there is evidence from ponderosa pine (*Pinus ponderosa*) forest ecosystems in the Gila and Saguaro Wilderness Areas of the Southwest that suggests that WFU will help reduce the density of small-diameter trees without significantly impacting the density and condition of larger trees (Holden et al. 2007). Holden and colleagues (2007) also suggest that WFU has helped restore forest ecosystem resilience to fire, as forest stands have become more structurally complex, a goal identified by many of the participants of this study. Of the respondents in this study, only the land managers associated with the USFWS's land base have an existing WFU program (USFWS 2008).

Conclusions

The results of this study highlight the specific objectives and perceived risks and benefits that play a role in the selection and evaluation of various forest and fire management alternatives in the mixed-pine ecosystems of eastern Upper Michigan. The simple means-ends network shown in Figure 3 identifies the fundamental or ends objectives, those that matter the most to land managers, as well as the means objectives, or those that are not fundamentally most important but may be necessary to achieve an ends objective (Keeney 1992). The influence arrows identify the connection between a particular means objective and the final ends objective, as reflected by respondent interviews.

There was some consensus among participants regarding fundamental or end ecological objectives. Most participants indicated that they wanted to promote biodiversity and restore ecosystem integrity (Figure 3). Participants also recognized the importance of fire in mixed-pine forest ecosystems but found it difficult to implement in practice. They wanted to minimize both short- and long-term risk, while allowing natural fire to play a role without placing socioeconomic objectives in danger. There is a fairly clear consensus that fire (prescribed or wild) has the potential to benefit wildlife and habitat but places fundamental socioeconomic objectives (public safety, forest products, property, and public desires) at risk (Figure 3). The idea of choosing between benefits to wildlife habitat versus risks to human health and property is a trade-off that involves protected values, or those that people are uncomfortable negotiating (Baron and Spranca 1997). Making trade-offs among protected values, where you give up something on one objective (e.g., place a threatened species in danger) in order to gain something on another (e.g., protect homes), are often difficult, if not impossible, for people to address (Tetlock et al. 2000). When these difficult trade-offs are combined with uncertainty about ecosystem function and the factors that regulate ecosystem structure such as fire, as well as institutional mandates, the default may be to rely on decision shortcuts that result in the avoidance of the perceived "risky" choice (WFU or prescription) (Maguire and Albright 2005).

The results presented here inform the first two steps of a structured decisionmaking approach aimed at reducing uncertainty in mixed-pine ecosystem management and assisting managers in making the difficult trade-offs that are required. In-depth feedback from land managers identified both the means and ends objectives, and specific management tools that may be useful for achieving what is ultimately most important for that particular agency or organization (Figure 3). Next, the best available scientific and technical data will be used to characterize the impacts or consequences of the various alternatives on the fundamental or ends objectives (Step 3). 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 (Step 4) and ultimately more informed management decisions (Step 5). 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.

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