Forest Stewards Guild

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Wisconsin Forest Practices and Harvesting Constraints Assessment

REPORT

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Shawn Hagan (large cover photo), Carly Lapin, WIDNR, Wood turtle (small cover photo) Mike Lynch (facing page)

EXECUTIVE SUMMARY

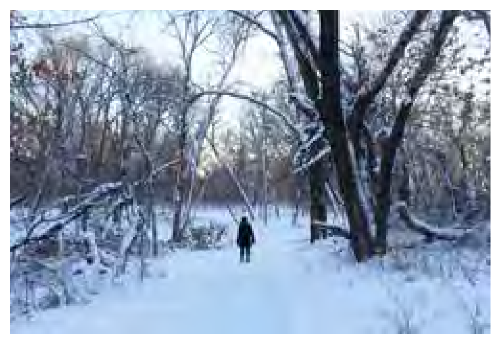
Wisconsin's 16 million acres of forestland are crucial to the well-being and wealth of all Wisconsin citizens. In 2012, the Wisconsin forestry and forest products industry directly added $23 billion to the state's economy. Other forest benefits such as recreation, hunting, fishing, and clean water also have a large economic impact. For example outdoor recreation, hunting, and wetlands contribute $12, $1.8, and $3.3 billion dollars to the Wisconsin economy respectively. Protecting and enhancing the value of forests and the forestry sector in Wisconsin is critically important. Because forests and forestry provide a wide range of benefits to many different sets of stakeholders, any effort to enhance one benefit may constrain or limit other benefits. Balancing those benefits between different interests and across various timescales is an ongoing challenge for policy-makers and for leaders in the forestry community.

Timber harvesting and other forest management operations are affected by a broad suite of factors, including but not limited to, regulations, guidelines, professional judgements, landowner decisions, and weather related conditions. Throughout this report we use the expression *forest management constraints* to refer to this broad set of factors, both regulatory and non-regulatory, that affect both timber harvesting and other forest operations. This study focuses on constraints on forestry management that are designed to protect or enhance forest productivity, safeguard populations of rare animals, reduce the impact of forest pests, or control invasive species. **The purpose of this study is to evaluate the collective impact of constraints on forest management and to assess the economic and ecological consequences of those constraints.**

To understand consequences of forest management constraints, we carefully reviewed the existing scientific literature, mapped affected areas, analyzed harvest cases studies, conducted surveys of foresters and timber professionals, assessed ecological impacts, and modeled economic effects. In order to assess the economic impacts of forest management constraints, we modeled an economic scenario wherein a change in constraints expanded the logging season by 30 days. Based on our harvest case study data, scoping assessment of most important constraints, we estimated that the most plausible scenario was a one-month increase in the logging season, which we further estimated to be between five and ten percent of the existing logging output. A change in model assumptions or input values would yield different results. Our model excluded potential impacts on paper or lumber mills and the inclusion of these sectors would change the results.

The costs of forest management constraints are not evenly distributed across organizations, individuals, or geography. Forest management constraints can have a disproportionately large impact for timber professionals, primary wood processors, and forest-based businesses. The timber professionals we surveyed indicated that the types and magnitudes of impact on their operations vary greatly between businesses. This variability in impact was also observed by foresters. Public agency foresters reported a smaller impact of constraints on their organizations compared to foresters working for mills, for loggers, or for industrial timberland owners.

The summer months have the most accumulated constraints. Overall, forest management constraints have a larger impact in the southern counties due to the higher prevalence of oak wilt, annosum root rot, invasive species, and the generally shorter winter logging seasons. Constraints around oak wilt and frozen



Mike Lynch (top)
Fred Clark (lower)
Mike Lynch (page 1)

Mike Lynch

ground affect the largest area and cause the greatest impact by creating prohibitions on harvesting, which create a greater impact than an added cost or adjustments to operations alone. However, these same constraints are likely to have the most direct economic benefit for long-term forest productivity.

Our analysis of the ecological consequences of forest management constraints indicates that overall, guidelines, best practices, and other constraints intended to protect forest resources have positive effects on forest composition and structure and in protecting forest productivity. These constraints also have less economically tangible, but equally valuable, positive outcomes for wildlife, biodiversity, and water quality. It is important to note that we evaluated the impacts constraints bases on their stated objectives and direct measurement of their effectiveness was beyond the scope of this study. While all the harvesting constraints and best practices we studied are based on science and are developed with scientific input, little research is available on the efficacy of constraints as they are applied. A notable exception is the application of water quality BMPs, which research has shown to be effective. Responses to our survey of practitioners about the effectiveness of constraints may provide useful information for future field studies on the issue.

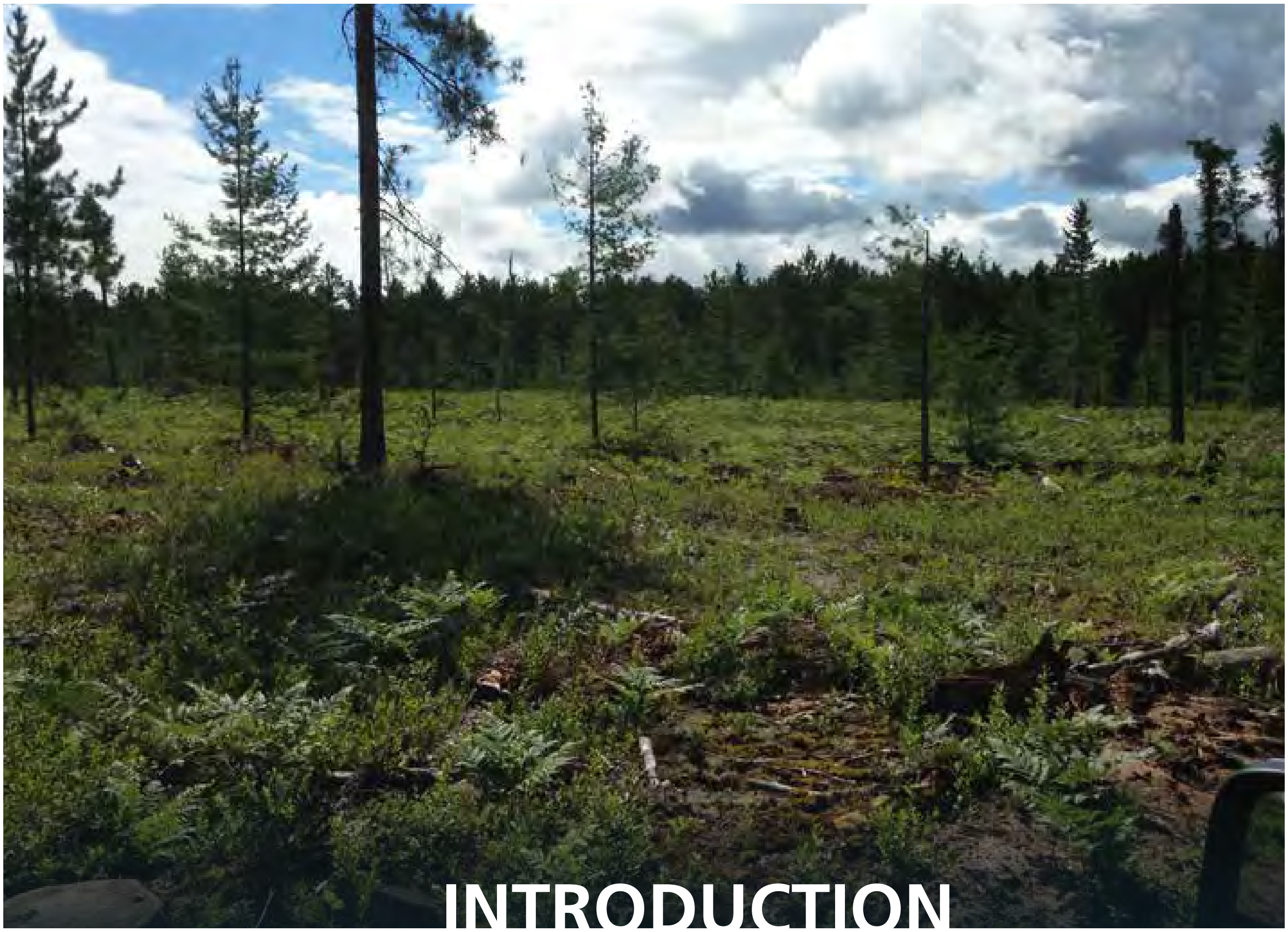
While the implementation of forest management constraints causes immediate economic impact, the forest resources these constraints are designed to protect also have significant present and future value. The economic benefits of removing or adjusting constraints should be weighed against the benefits of protecting forests through forest management constraints. Those benefits are less tangible and less-easily measured, but they are no less important and are widely valued by society and by taxpayers who support forestry programs. Other factors outside the scope of this study such as the size of forest holdings, distance to roads, population density, and owner attitudes toward harvesting also affect timber availability in Wisconsin. These other constraints may have greater impacts on forestry operations without protecting social, environmental, or economic benefits.

Most foresters and timber professionals recognize and support forest management constraints that protect forest health, forest productivity, and other conservation values. In our survey, over 70 percent of timber professionals indicated they believed protecting forest resources and values was either extremely or moderately important. In most cases, foresters and timber professionals apply constraints primarily based on professional judgment. In conversations, several practitioners noted that they would adhere to and continue to apply most constraints in some form regardless of whether they were required to do so by regulations or other mandatory requirements because they feel ethically obligated to apply the best science to their work and to act to protect the long-term values of the forest resource.

It may be possible to adjust forest management constraints so that they better balance positive and negative impacts; however, any adjustments must be based on sound science. For a more detailed discussion of the study's results, please see the *Synthesis* section.

Steven Katovich, US Forest Service (top)
Mike Lynch (middle and lower)

Mike Lynch (page 5), Fred Clark



INTRODUCTION

BACKGROUND

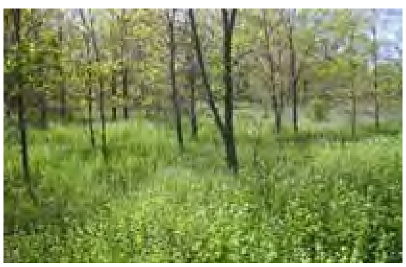
Forests are crucial to the ecological, economic, and community well-being of Wisconsin. In 2012, Wisconsin's forestry and forest products industry directly added $23 billion to the state's economy, and other forest benefits such as recreation, hunting, fishing, and clean water make a similarly large economic impact. For example, outdoor recreation, hunting, and wetlands contribute $12, $1.8, and $3.3 billion dollars to the Wisconsin economy, respectively ((OIA 2013, IAFWA 2002, Earth Economics 2012). Therefore, it is important to protect and enhance the value or forests and forestry in Wisconsin. Because forests and forestry provide a wide range of benefits, efforts to enhance one benefit may constrain or limit other benefits. For example, expending resources to protect forests from invasive species may negatively affect the economic benefits of a particular timber harvest.

Timber harvesting and other forest management operations are affected by a broad suite of factors including, but not limited to, regulations, guidelines, professional judgements, landowner decisions, and weather-related conditions. Throughout this report, we use the expression *forest management constraints* to refer to the broad set of regulatory and non-regulatory factors that affect timber harvesting and other forest operations. This study focuses on forest management constraints that are designed to protect or enhance forest productivity, safeguard populations of sensitive animals, or control invasive species. **The purpose of this study is to evaluate the collective impact of constraints on forestry activities and to assess the economic and ecological consequences of those constraints.**

Concern in Wisconsin about information gaps about the costs and benefits of forest policies, regulations, and guidelines resulted in the Wisconsin legislature approving funding for focused forest practices studies in the 2013-2014 state budget. Based on the legislative directive in Wisconsin Statute 26.105(1), the Wisconsin Department of Natural Resources awarded a grant to conduct the Wisconsin Forest Practices Study (WFPS) to the Great Lakes Timber Professionals Association (GLTPA) and Wisconsin County Forests Association (WCFA). More information on the WFPS Plan is posted at http://study.wisconsinforestry.org.

GLTPA and WCFA used a consultative process with the Wisconsin Council on Forestry to guide the forest practice studies. The Forest Stewards Guild responded to the Wisconsin Forest Practices Study – Request for Proposal 2.0 in September 2014 and was chosen through a competitive process to conduct the 2.0 portion of the WFPS. The request for proposals included an analysis of three questions:

1. What is the scope of selected timber harvesting restrictions in Wisconsin, and the potential for the restrictions to shift forest harvesting from summer to winter months?
2. What are the economic consequences of the timber harvesting restrictions identified in question 1?
3. What are the ecological consequences of the timber harvesting restrictions identified in question 1?



Steven Katovich, US Forest Service, Garlic mustard (top)
US Forest Service (lower)

Our study shows that timber harvesting and other forest management operations are affected by a broad suite of factors including, but not limited to, regulations, guidelines, professional judgements, landowner decisions, and weather-related conditions. We assessed the impact of forest management constraints designed to:

1. Prevent or control the spread of forest health threats and forest invasive species including:
   - Oak wilt
   - Annosum rot root
   - Garlic mustard
   - Buckthorn
   - Honeysuckle species
2. Protect or enhance populations of rare, threatened, or endangered species, including:
   - Wood turtle
   - Northern goshawk
3. Maintain forest productivity and minimize water quality and environmental impacts by reducing or eliminating the following impacts during harvesting and forestry operations:
   - Soil compaction
   - Rutting and erosion
   - Excessive reduction of soil nutrients.

To fully address the questions about the ecological and economic impact of forest practices and forest management constraints, the Forest Stewards Guild engaged ecologists with Applied Ecological Services of Brodhead, WI and economists from the Bureau of Business and Economic Research at the University of Minnesota-Duluth. This study complements another report contracted to address the same RFP written by a team from the University of Wisconsin-Stevens Point (UWSP) titled *The Scale and Cost of Seasonal Harvesting Restrictions in Wisconsin*. This report would not have been possible without the insights and data provided by land managers, forests, timber professions, and mill owners across Wisconsin. We hope the results will aid decision-making and policy development for the future of forests and forestry in Wisconsin.

REPORT CONTENTS

To address these questions, we used existing geospatial data, scientific studies, agency reports, and expert opinion to assess the current scope of forest management constraints. The following sections of this report analyze constraints using five assessment methods: mapping, harvest case studies, forester and timber professional surveys, economic analysis, and ecological impact assessment. Each of these assessment methods is described in more detail below.

Forest Management Constraints

The first section provides background on the threats facing Wisconsin forests and the forest management constraints designed to mitigate those threats. We conducted a thorough review of the existing scientific literature on the interaction between forest operations and each of the constraints. Open meetings with timber and forestry professionals in Richland Center and Rhinelander helped refine our analysis firsthand knowledge and insights. We also worked closely with forest managers and timber professionals to learn specifically how constraints play out on the ground.

Assessment of Constraints through Visualization across Space and Time

Mapping each of the constraints both geographically and temporally helps visualize the impact of individual and cumulative impacts. We combined geospatial datasets in GIS-based analyses to map forest management constraints. The results show where and when constraints accumulate.

Assessment of Constraints through Harvest Case Studies

Land managers at the Board of Commissioners of Public Lands, Marathon County, The Forestland Group, Kickapoo Woods Cooperative, and other private forestry consultants shared real-world examples of forest management constraints at the parcel or tract scale from 170 timber sales in 23 counties over a five-year period. We analyzed their timber sale documentation including timber sale prospectuses, restrictions applied, and corresponding sale prices to assess the impacts of forest management constraints. The harvest case studies provide crucial insight into how constraints affect pricing.

Assessment of Constraints through Forester and Timber Professional Survey

To ensure our case study data were representative of conditions across the state, we conducted two surveys. One survey of practicing foresters was conducted jointly with UWSP. The other survey of timber professionals was conducted in partnership with the GLTPA. The results of both surveys are described in detail in this section and provide insight into why and how constraints are put in place.

Assessment of Economic Effects

Both the survey results and the harvest case studies from our land management partners were used as inputs to the economic modeling phase of the project. As described in greater detail in the *Assessment of Economic Effects* section, we used detailed case studies, harvest data, and survey responses to assess the costs and implications of forest management constraints. The economic impacts identified in the case studies were extended to the entire state using economic modelling software.

Assessment of Ecological Effects

The sixth element of the project examined ecological consequences of timber harvesting constraints. We assessed the impact of the constraints addressed in the study on forest structure, composition, and productivity; wildlife habitat; biodiversity; and water quality.

Synthesis

The *Synthesis* section captures themes that emerged from the combined quantitative data and qualitative information gathered from these assessments to develop conclusions about the economic and ecological effect of forest harvesting constraints. By drawing on multiple lines of evidence, the synthesis creates a holistic view of impacts, both positive and negative, of forest management constraints in Wisconsin.

Richland Center listening session, Mike Lynch


US Army Corps of Engineers, St. Paul District

FOREST MANAGEMENT CONSTRAINTS

BACKGROUND

A variety of forest practices and harvesting constraints exist to protect forest productivity and health and other forest benefits. Constraints on timber harvesting and other forestry operations can take various forms, including:

1. Mandatory requirements which carry the force of law, such as regulations
2. Quasi-mandatory requirements such as those requirements imposed as a term of contract or by professional organizations as part of third-party certification or professional accreditation
3. Voluntary guidelines that are recommended but not required
4. Independent judgments made by foresters, timber professionals, or forest landowners.

This study focuses on the constraints on forestry operations identified in the RFP that are designed to enhance forest productivity, protect populations of sensitive animals, or control invasive species.

Some of these constraints prohibit all forestry activities in a particular place or at a particular time, while others can require adjustments to the scope, scale or timing of forestry operations. To identify the most critical constraints, we consulted with foresters, loggers, and academics involved in managing public and private forests across Wisconsin. The listening sessions helped get to the heart of each of the major issues in question. Throughout this section, we describe feedback from attendees at our listening sessions. Unlike the quantitative survey and case study data described later in the report, listening session input was qualitative and has been treated as such in our study.

This section describes the issues and constraints. The impacts of these constraints are assessed in subsequent sections.

PREVENTING OR CONTROLLING THE SPREAD OF FOREST HEALTH THREATS

Oak wilt

Oak wilt (*Ceratocystis fagacearum*) kills trees quickly and is currently present in 60 of Wisconsin's 72 counties (Juzwik et al. 2010, WCF 2015). The primary means of spread of this fungus are through root grafts between adjacent trees and through insect vectors (Menges and Loucks 1984). The disease remains active in stumps of harvested oak trees and can continue to spread (Tryon et al. 1983). Forest succession after mortality caused by oak wilt tends to shift towards shade-tolerant and/or non-canopy-forming species such as black cherry and box elder (McCune and Cottam 1985). Guidelines to reduce the impact of oak wilt in Wisconsin suggest shifting harvests away from the summer months when oak wilt is more easily transmitted. Other treatment options that have been explored include root graft disruption (severing) between oaks. This method, though labor-intensive, has a 54 to 100 percent efficacy rate for halting the spread of this disease (Koch et al. 2010). In general, if there are oak wilt infestations nearby releasing spores, there is a risk of transmission to freshly cut stands between April (April 1st in the south or April 15th in the north) and July 15th. Specific guidelines on timing oak harvests to minimize the risk of oak wilt spread are provided by the DNR (WIDNR 2007, Cummings Carlson et al. 2010).

In our listening sessions, we heard from foresters and timber professionals that oak wilt as a major constraint that impacts their ability to operate in the woods during mid-summer. Listening session attendees in central Wisconsin counties expressed greater concern with this constraint compared to attendees from the northern counties, which is likely due to oak wilt's relatively recent appearance in this region and extent of oak forests on sandy soils in which oak wilt spreads most aggressively.

Annosum root rot

Annosum root rot (*Heterobasidion irregulare*) is a fungal disease that kills red and white pine tree stands and has been confirmed in 23 southern Wisconsin counties. This disease affects planted tree crops more than natural forestland (WIDNR 2016b). The fungus can remain viable in roots and stumps of felled trees for decades, which can spread to future stands (Cleary et al. 2013).

To control annosum, managers on state-owned lands are required to follow recommendations prescribed in *A risk-based guide for the fungicide treatment to prevent annosum root rot in Wisconsin;* use of these guidelines is recommended on private lands as well. The annosum guide calls for the application of a borax-based fungicide in high-risk locations from April 1 to November 30. While many timber professionals have adapted and can efficiently apply fungicide as part of their harvest operations, additional costs are created when they invest in treatment equipment and Commercial Pesticide Applicator certification as required by state law.

Other treatment options include stump removal, which has a disease removal success rate ranging from 20 to 72 percent, or the use of the biological agent *Phlebiopsis gigantea* on freshly-cut stumps (Cleary et al. 2013). Attendees at both listening sessions identified practices that slow the spread of annosum as major impacts on their ability to accomplish work due to the time needed to outfit equipment with the fungicide applicators and train and license staff for fungicide application. Timber professionals that do not use processors indicated the fungicide application can complicate their process and adds time and expense to their projects. Timber professionals that rarely work in pine forests said this constraint does not impact them at all.

PREVENTING OR CONTROLLING THE SPREAD OF INVASIVE SPECIES

The 2004 Wisconsin Conference on Forestry (organized and hosted by the Wisconsin Council on Forestry) identified invasive exotic species as one of the greatest threats to the long-term health and sustainability of Wisconsin's forests. In response, the Council led the development of consensus-based, voluntary invasive best management practices for forestry (WCF 2004). These voluntary guidelines recommend that managers take steps to minimize the spread of invasive plants such as scouting for invasive species infestations before harvests and cleaning equipment before leaving sites at times when soil and plant materials can be easily transported between sites. The guidelines recommend that timber professionals scrape or brush soil and debris from exterior surfaces before moving equipment onto and off of harvest site.

Fred Clark

We selected garlic mustard, buckthorn, and honeysuckle as representative of invasive plants because they generally have the broadest distribution and are considered to have the greatest impacts in Wisconsin forests. In practice, forestry operators tend to group invasive plants into one category rather than separate species because the impact (equipment cleaning) is largely the same for all invasive plant species. A few listening session attendees felt that the need to clean their equipment was onerous and that it cost them an extra day between jobs. Others indicated that these constraints are not terribly onerous on their operations. However, many attendees felt their efforts were ineffective because recreational forest users (ATV, camping, etc.) were not held to the same standard of cleaning. The inequity of cleaning guidelines was a major concern. At the Rhinelander listening session, attendees identified the Emerald Ash Borer (EAB) quarantine at mills as a major issue for regional forestry. Foresters and timber professionals across the state occasionally encounter challenges with storing ash logs because of EAB.

PROTECTING POPULATIONS OF THREATENED OR ENDANGERED SPECIES

In addition to state forest practices guidance, both state and federal governments create regulations designed to protect rare species. These regulations can have significant economic impacts (Plantinga et al. 2014). While over 60 vertebrate animals and dozens of invertebrates and plants are listed as threatened or endangered in Wisconsin, a much smaller number of species generate habitat or conservation needs that create a significant limitation on forest operations. Species with the greatest likelihood of triggering regulatory constraints include:

Wood turtle

Wood turtle *(Clemmys insculpta)* is a State Threatened species in Wisconsin. While forestry operations that create or maintain sandy openings can greatly benefit wood turtles, a 300-meter buffer around suitable wood turtle habitat is required from May 15 to September 15 for some projects. Both of our listening session groups indicated that wood turtle constraints sometimes create significant limitations on operations, although they generally have a larger impact in northern Wisconsin. Wood turtles are found across much of the state except for the southern and southeastern regions. Wood turtle habitat includes rivers and perennial streams, adjacent wetlands, and nearby forested and semi-forested uplands; the majority of its time is spent within a riparian zone of about 100 meters (Higdon et al. 2005). Wood turtles are threatened by a variety of factors including removal and handling by humans, vehicle kill, and disturbance by dogs (Gibbons et al. 2000). There are also data indicating that the species has very specific riparian zone nesting requirements in terms of substrate and humidity, and changes in these factors affect reproductive success. Loss or degradation of such sites may put the species at risk (Hughes et al. 2009).

Northern goshawk and other forest-nesting birds

Forest operations within one mile of an occurrence of northern goshawk (*Accipiter gentilis*) require a survey showing absence in the project area, avoidance measures from February 1 through July 31, or activities scheduled between August 1 and January 31. Northern goshawks live in mature forest, and most of the occurrences are in northern Wisconsin. A number of other forest interior birds such as the cerulean warbler (*Setophaga cerulea*), Acadian flycatcher (*Empidonax virescens*), and other state-protected forest-dwelling birds also require protection because of their status. If logging is to occur within one mile of a previously documented occurrence of one of these, either surveys demonstrating absence or a summer avoidance period from May 1 to the end of August would be recommended. In our listening sessions, forest managers and timber professionals indicated that regulations protecting these or other interior song birds did not often limit harvest operations.

Northern long-eared bat

Northern long-eared bat (NLEB; *Myotis septentrionalis*) has been listed as Threatened under the Endangered Species Act (ESA) by the U.S. Fish and Wildlife Service because the population has been decimated in many eastern states by the introduced disease known as white-nose syndrome (WNS). Currently, WNS is spreading westward and is established, but not widespread, in Wisconsin. At the time this study commenced, a final rule had not yet been issued under Section 4(d) of the ESA. For that reason, we excluded the NLEB harvest constraints from our analysis.

Zander Evans

PROTECTING FOREST PRODUCTIVITY AND WATER QUALITY

Compaction and related byproducts of forest operations can reduce the productivity of forest soils, cause erosion of surface soils, and, without proper implementation of forestry best management practices (BMPs), cause deposition of sediments and contaminants into surface water bodies. In some cases, large harvest equipment can cause compaction of soils, particularly in wetter areas, or rutting in fine-particle or poorly-drained soils, thereby compromising future productivity (Stone 2002, Bustos and Egan 2011, Kolka et al. 2012). A variety of tactics may be employed to minimize these impacts, including timing harvest operations to occur on frozen or dry ground, and selecting logging equipment that is matched to the soil and site to minimize compaction and rutting. Detailed guidance on protecting soil productivity and water quality is provided in Wisconsin Best Management Practices for Water Quality, and more broadly in the *Wisconsin Forest Management Guidelines* (2011).

All of the evidence we collected reinforced the generally accepted view that solid ground and frozen ground constraints have a major impact on logging operations throughout Wisconsin. Although adhering to soil and water quality constraints may be inconvenient, allowing operations which damage those resources will be harmful to forest productivity and could harm public support for forestry. Several listening session attendees said they felt soil and water quality constraints were less of a government restriction than a natural or "mother nature" type of restriction.

Several listening session attendees also noted that the duration of frozen winter ground conditions has generally decreased over the last few decades. With increasingly variable and shorter winter logging seasons, the widespread use of winter-only harvesting constraints has the potential to create bottlenecks in forest operations and cause severe economic hardships for some timber professionals, sawmills and forest landowners. For example, timber professionals may not be able to complete contracts on time if frozen ground is required. Studies have found summer access to timber was important for loggers and that seasonal constraints can cause economic hardship (Kueper et al. 2014, Blinn et al. 2015). Moreover, timber professionals' ability to adapt to changing climate conditions such as earlier spring break-up may be limited by high operational costs, low timber prices, and large equipment investments (Geisler et al. *In press*).

Wisconsin's BMPs for water quality are designed to protect water quality in lakes, streams and wetlands with simple and cost-effective practices before, during, and after forestry management activities (WIDNR 2011). In some cases, water quality BMPs are implemented by limiting harvest to frozen ground conditions. For example, one recommendation for riparian zones is to operate wheeled or tracked equipment within 15 to 50 feet of the ordinary high water mark only when the ground is frozen or dry. Monitoring data clearly show that on the vast majority (greater than 90 percent) of timber harvests in Wisconsin, water quality best management practices are applied correctly (Kafura and Kriegel 2015b, a).

Biomass harvesting guidelines

The Wisconsin Council on Forestry led a consensus-based process to develop biomass harvesting guidelines, which were first implemented in 2009. Biomass harvesting guidelines are a relatively new addition nationally to the spectrum of forest management constraints and are designed, in part, to protect forest productivity (Peckham and Gower 2011, Evans et al. 2012, Rittenhouse et al. 2012). Curzon and colleagues demonstrated productivity declines on some soils when harvest residues were removed on the Huron National Forest of Michigan (2014). Biomass guidelines have emerged as the market for wood as an energy feedstock has grown in Wisconsin (Luppold et al. 2011, Tyndall et al. 2011).

The current Wisconsin Biomass Harvesting guidelines list hundreds of specific soil map units that are nutrient-poor and unlikely to support sustained biomass removal without some limitations (Bronson et al. 2014). Some listening session attendees indicated that there were no restricted soils in their area, while others said they work in areas with a lot of restricted soils. The variability of the impacts of biomass harvesting constraints were driven by the section of the state, the existence of a biomass industry in the area, and the soil conditions.

OTHER CONSTRAINTS

Other important constraints affect when and where timber can be harvested. Butler and colleagues (2010) estimated that social constraints (the size of forest holdings, distance to roads, population density, and owner attitudes toward harvest) reduced wood availability by about 52 percent in Wisconsin. Changing land tenure patterns can also restrict the harvest of wood products. Transfer of industrial timberland caused up to a five percent reduction in the volume of wood extracted in one study (Gustafson and Loehle 2006). As parcel size shrinks in an area, it becomes harder and harder to economically harvest timber in that area (Hatcher et al. 2013, Conrad 2014). Haines and colleagues (2011) documented the negative impact of forest parcelization on timber availability in Bayfield County, Wisconsin. Another study highlights the influence of ownership types, proximity to markets, and surrounding forest cover on harvest activities in four widely separated Wisconsin Counties (Bowe and Bumgardner 2006).

Mike Lynch

During the listening sessions, attendees mentioned forest certification (specifically Forest Stewardship Council [FSC] certification) as a constraint. Even when forestland is not under certification, Certified Master Loggers and Certified Foresters generally apply many of the standards of FSC or the Sustainable Forestry Initiative. Part of the frustration with certification came from a feeling that it brought little financial advantage because there was little demand for certified wood in the southern part of the state and a glut of certified wood in the north. However, some attendees pointed out that certification does not dictate constraints, but it asks that the local constraints be implemented.

Forest ownerships in southern Wisconsin are heavily dominated by small family forests. Forest operations in these ownerships are often significantly constrained by forest owners' recreational activities, especially hunting during the gun deer season. This issue was identified by many of the attendees at the Richland Center listening session. Because the traditional gun deer season comes in late November after other constraints have been lifted, the effect during what should otherwise be prime logging season is often particularly disruptive. The nine-day gun deer season is a period when many private forests are unavailable for logging, and many forest owners go further by restricting any woods activities for a period of time prior to the gun-deer opening to avoid scaring deer or disrupting seasonal patterns.

Many timber professionals said they have a hard time finding available harvests in the region between September and December because of the four-month-long bow season. Crop-off constraints are an issue in the southwestern region because nearly all forests are accessed through agriculture fields and the farmers will not allow access except in the winter. Due to Natural Resource Conservation Service policy, many timber professionals report they

Zander Evans

are not allowed to drive across or deck logs on conservation reserve program (CRP) fields. Listening session attendees identified limits on log truck weights at the local level as an additional barrier to efficiently harvesting and moving timber.

CHANGES IN HARVESTING CONSTRAINTS

Individually, the constraints on forest operations described above may be manageable for most operators. However, there is a real potential for the number of constraints to grow and interact to create more significant disruptions for forest operators, ultimately limiting the ability to effectively manage in some areas.

The date of the last spring freeze has recently been arriving earlier by as much as two weeks in northwestern Wisconsin than in the 1950s (WICCI 2011). The period of frozen ground conditions has shortened by two to three weeks in Wisconsin between 1948 and 2012 (Rittenhouse and Rissman 2015). Warmer winters with higher low temperatures, combined with higher summer temperatures, are expected to increase the spread of several forest pests, diseases, and invasive species, including annosum root rot, emerald ash borer, and buckthorn (Bradley et al. 2010, Janowiak et al. 2014, Handler et al. 2014). The greater extent or more frequent occurrence of these factors can be expected to affect some forest types and tree species more severely than others. To the extent that the future climate-influenced effects of pests, diseases and invasive species interact with forest harvest restrictions, those restrictions could impact future business scenarios for the timber industry.

Mike Lynch

ASSESSMENT OF CONSTRAINTS THROUGH VISUALIZATION ACROSS SPACE AND TIME

METHODS

Mapping constraints geographically and temporally helps with the visualization of individual and cumulative impacts (Figure 1 page 19). In our maps, red depicts areas with constraints. Some constraints do not completely prohibit harvest, but rather add costs or time to harvesting operations. For example, recommendations to apply fungicide to reduce the spread of annosum root rot or to clean vehicles to slow the spread of invasive plants increase the cost of operations, but do not eliminate the opportunity to harvest timber. These types of constraints are depicted with lighter shades of red. In the case of invasive plants, counties with a combination of garlic mustard, buckthorn, and honeysuckle are a darker shade of red while counties with only one of these invasive plants is a lighter shade of red. Areas with constraints for part of the month are depicted with red hash marks. For example, only portions of February or December are likely to be available for harvest in areas that require frozen ground, so our maps depict these months with hashing.

Data availability and a mismatch of scales limit the precision of our mapping. The maps of constraints are only as good as the underlying data. For example, exact maps of when frozen ground conditions exist are not available. However, a recent report does provide useful temperature data for key locations across the state (Rittenhouse and Rissman 2015), which we used for our map of frozen ground conditions.

A number of attributes were only available at a county scale; for example, the distribution of forest pathogens and invasive plants. County-scale maps provide a rough estimate of where constraints may be applicable, but they cannot capture the local features that drive many constraints. For example, oak wilt constraints are driven in part by proximity to occurrences of oak wilt in the stand, which cannot be predicted from the county maps of infection. The entire state is marked as constrained by lack of frozen ground even though stands that require frozen ground for operations only occur in particular locations across the state.

Mapping wood turtle habitat, and the potential for it to cause forest management constraints at the township level, greatly overstates the extent of the true area. Wood turtle habitat is measured on the order of meters, but DNR guidance requires mapping of this threatened species at the township scale.

The DNR further restricts the public availability of data on northern goshawk by only allowing it to be displayed at the county level. Therefore, to reduce the overestimation of the impact of goshawk constraints, we took a modeling approach. We overlaid maps of hardwood and mixed hardwood-pine forest types with maps of mature forests within the Wisconsin counties in which northern goshawk occur (WIDNR 1998, Pan et al. 2015). Though the resulting map does not depict actual areas used by northern goshawks (and so can be displayed without violating confidentiality agreements), it is a better representation of the portion of the state that might be impacted by northern goshawk constraints (though still an overestimate).

RESULTS

The combined map of constraints (Figure 1) is not a quantitative depiction of the exact impact of forest management constraints because of the limitations of data availability and scale. However, the combined does highlight some important patterns. Summer months have the most accumulated constraints. In May, June, and July, all the constraints we considered in this study are relevant. Many of the constraints have a larger impact in the southern portion of the state; most notably, oak wilt, annosum, invasive plants, and frozen ground during the shoulder seasons. Oak wilt and frozen ground constraints have the potential to cover the greatest area with an outright prohibition against harvesting (as opposed to simply an added cost or requirement adjustment to operations).

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Summary

- Summer months have the most accumulated constraints on timber harvesting.
- Many constraints have a larger impact in the southern portion of the state such as oak wilt, annosum, invasive plants, and frozen ground during the shoulder seasons.
- Oak wilt and frozen ground constraints have the potential to cover the most area with a prohibition against harvest.

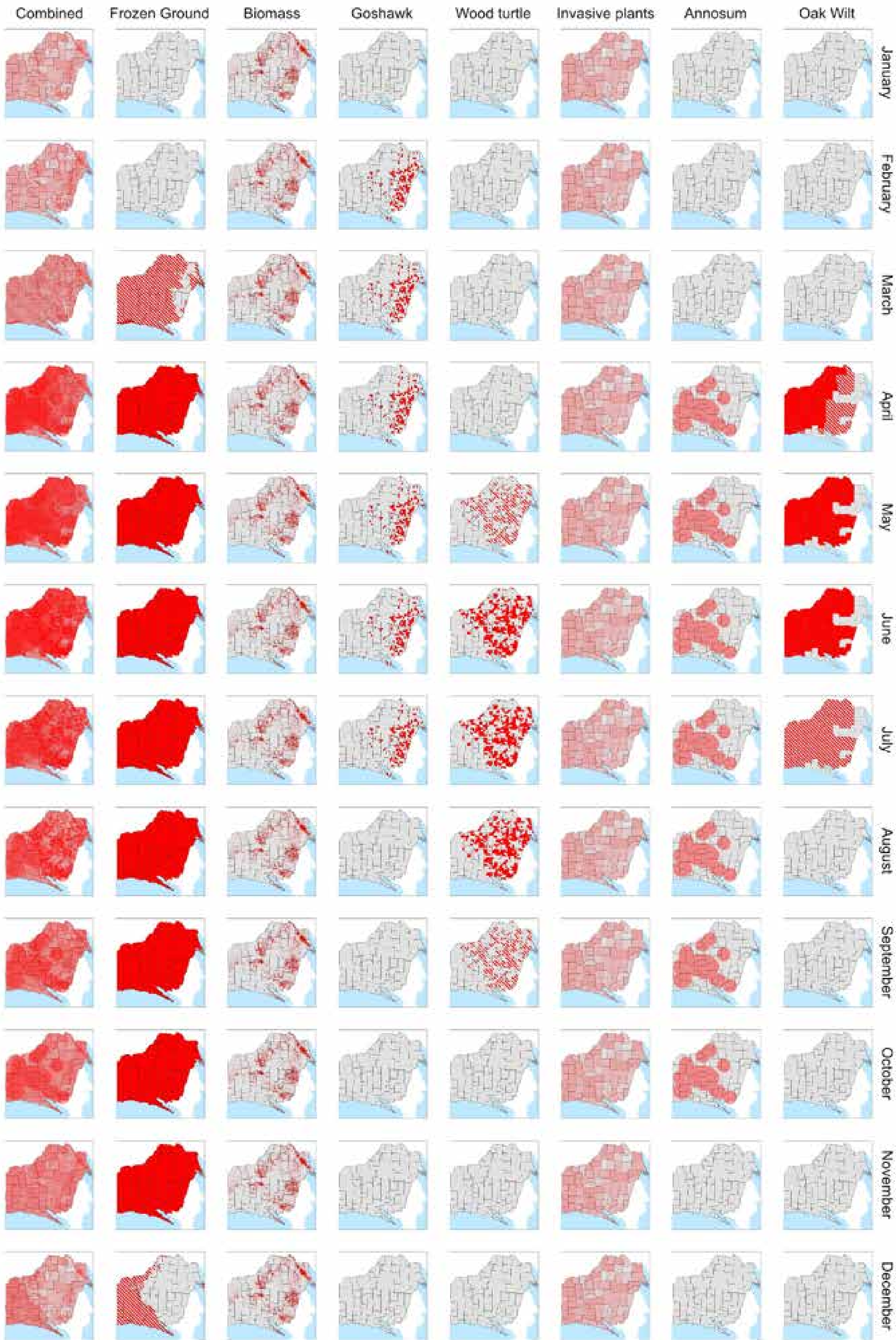

Figure 1 Maps of harvest constraints by month (for higher resolution, please see: www.forestguild.org/publications/research/2016/WFPS_figure_01.pdf)

Zander Evans

ASSESSMENT OF CONSTRAINTS THROUGH HARVEST CASE STUDIES

METHODS

We worked with landowners across Wisconsin to collect specific sale data to better understand the impact of constraints on logistics and timber sale pricing. We are indebted to land managers at the Board of Commissioners of Public Lands, Marathon County, The Forestland Group, Kickapoo Woods Cooperative and other private forestry consultant companies who collectively shared details of 170 timber sale records. Because some of these sales records include propriety information, only aggregated data are publicly available. Sale records covered 23 counties from across Wisconsin and included large, small, and public land owners. We divided sales by regions used by the U.S. Forest Service's Forest Inventory and Analysis (FIA) Program (Figure 2).

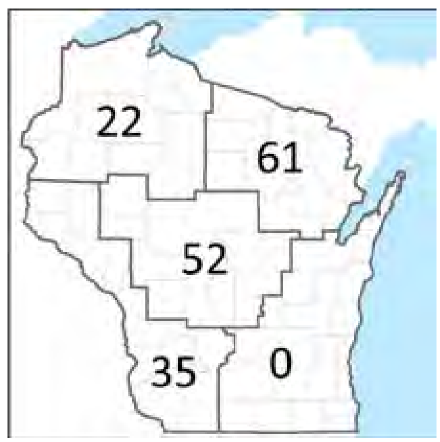

Figure 2 Number of sale records by FIA region

RESULTS

Individual timber sale descriptions and sale prices are crucial for understanding the impact of constraints because of their specificity. For example, the geographic scale of many constraints is measured in feet or yards rather than townships or counties. In other words, constraints can change the way timber is harvested on two adjacent acres. Similarly, pricing data aggregated at the county or even township scale would obscure the differences between upland and lowland sites. Summarizing pricing data by a quarter of a year would combine timber harvests that experienced some constraint with harvests that did not.

Most sales in our analysis specifically listed months of allowable operation or months of prohibited operation. Many also included a judgment statement that the logger should cease operation when the ground conditions caused excessive rutting or soil disturbance. In many cases, the specific reason for timing

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constraints was not explicitly described. When detail for a seasonal prohibition was provided, the specific reasons varied greatly. Of the 170 sales we examined, only eight (five percent) allowed for 12 months of operation. On average, constraints reduced the number of months of allowable operation to 6.5 (standard deviation [SD] 2.6). These 6.5 months are spread over the entire year, and which months are included differs greatly across the 170 sales.

Thirty-one sales (18 percent) had operation periods nine months or longer. The most common constraint (95 percent of sales) was one that prohibited logging in spring. Thirty-five percent of sales confined timber harvesting activities to winter months; however, only 19 percent explicitly stated frozen ground was required for harvest. Additionally, there were 17 sales (ten percent) that prohibited winter harvests, which was typically related to use of the forest for winter recreational activities such as cross-country skiing and snowmobiling. Summer access (specifically, August and July) was available on 62 percent of sales, but most of these sales included language requiring solid ground (i.e., relatively dry conditions). In our sample, the region with the longest average allowable harvest season was southwestern Wisconsin, while the northwestern region had the shortest harvest window (Figure 3).

Constraints changed prices for wood products. For example, in our sample, the average price for pulp was $41.52 per cord, however those sales that were restricted to frozen ground conditions had a significantly lower price $35.64. These prices were significantly different (p-value < 0.01). Pulpwood prices showed a significant increase when harvest was allowed in July. When harvesting was not allowed in July, the mean price per ton was $37.19, but when harvesting could occur during July, the price increased to $49.13. Sawtimber prices showed the opposite trend. Sawtimber prices were significantly higher for sales that were restricted to frozen ground conditions. Sawtimber from sales without frozen ground constraints averaged $257 per thousand board feet (MBF), while sales only available when the ground is frozen averaged $290 per MBF. In the spring, the situation was reversed. Sawtimber sales that permitted harvest during March had a higher price per MBF ($172 vs $249). However, pulpwood prices showed a decrease in price if March was available for harvest ($46.71 vs $41.60).

The harvest case study data may show the price impact of constraints that require frozen ground for harvest of pulpwood or prohibit sawtimber harvest in March. However, the same data show prices increased for pulpwood sales that prohibit harvest in March or sawtimber sales that require frozen ground. This counter-intuitive result may be caused by the fact that external factors can have a larger impacts on prices. For example, species and quality are important drivers of price and may be correlated with sites that can only be harvested when the ground is frozen. Sales that were more than thirty percent hard maple sold on average for $386 per MBF, while those that were less than five percent hard maple sold for an average of $202 per MBF. The overall volume of sawtimber is another example of a driver that increases sale prices. Many high-quality sawtimber sales may be scheduled for winter months to reduce the risk of log stain, the risk of site productivity impacts, or residual grade loss from damage during the growing season.

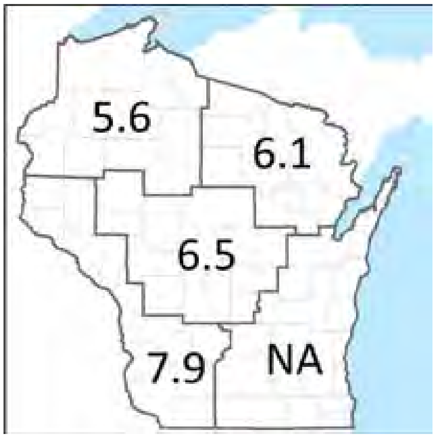
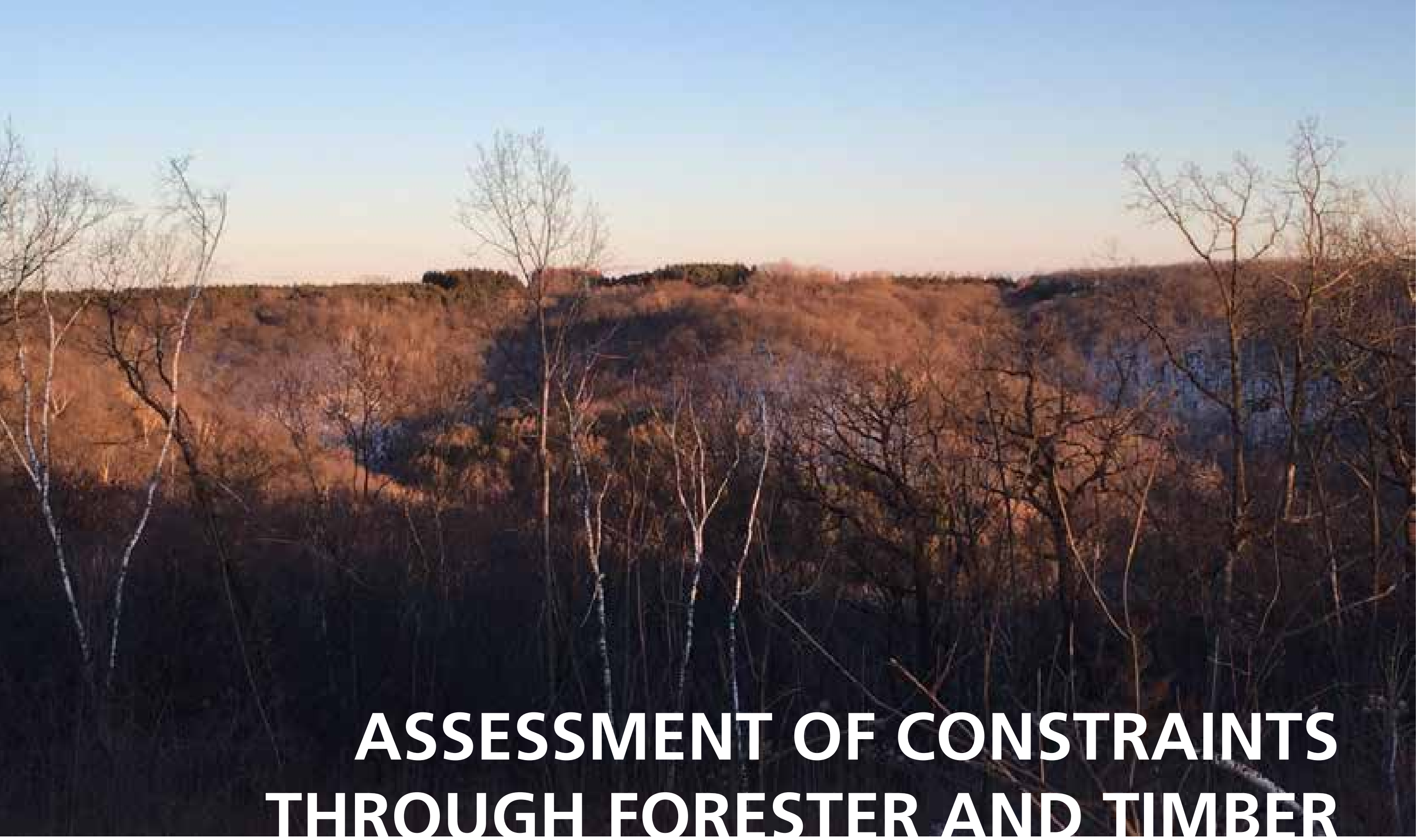


Figure 3 Average months of allowable operation

Summary

- Based on our harvest case studies, 95 percent of harvests had a seasonal constraint.
- On average, constraints reduced the number of months of allowable operation to 6.5, although the particular months of allowable operation varied greatly by sale.
- While 35 percent of sales required frozen ground another ten percent did not allow winter harvests.
- Including July in the operable months increased pulp prices by almost a third.
- Sale descriptions did not specify why seasonal constraints were applied and rarely identified where multiple constraints overlapped each other.



Mike Lynch

ASSESSMENT OF CONSTRAINTS THROUGH FORESTER AND TIMBER

METHODS

We developed two surveys to determine the operational impacts of forest practices and harvesting constraints. The *timber professional survey* was developed with review from external advisors. The *forester survey* was developed in collaboration with researchers from the UWSP and approved by the UWSP Institutional Review Board for the Protection of Human Subjects. Both surveys were open for three weeks from August 3rd to August 24th, 2015 using Survey Monkey, a web-based survey tool.

Both surveys were comprised of a unique set of questions for the target population; however, a few questions were posed in both surveys to investigate how these issues were perceived by individuals approaching the issue from different perspectives. A complete list of questions for both surveys is available in Appendix I.

Timber professional survey

The notice for the timber professional survey was distributed to 445 individuals though the Great Lakes Timber Professionals Association and the Wisconsin Master Loggers mailing lists. Of this population, 55 respondents participated in the survey and 48 fully completed the survey, giving us an estimated response rate of 12 percent. Respondents were from across the state with 27 of the 72 Wisconsin counties identified as the primary county of operation by at least one respondent. 77 percent of the timber professionals responding identified themselves as independent logging operators while the remaining 23 percent identified as a mill or primary wood user purchasing stumpage. Respondents identified as loggers or timber professionals conducted a median of 12 (mean of 25) timber sales per year with a median of 500 (mean 777) acres harvested annually. Thirty three timber professionals (90% of respondents) indicated on the survey that they also at least occasionally set up timber sales (i.e., establish timber harvests by defining harvest boundaries and prescriptions, set terms of harvest including restrictions, and oversee harvest operations).

Forester survey

The forester survey was distributed to 377 private consulting, industrial, county, state, and federal forester email addresses. Of this population, 245 participated in the survey, yielding a response rate of 65 percent. Fifty-four of the 72 Wisconsin counties were identified as the primary county of operation by at least one respondent. Sixty percent of survey respondents identified themselves as public agency foresters; 26 percent identified as consulting foresters working primarily with family forest landowners; 12 percent work for a mill, logger, or industrial forest landowner; and the remaining individuals indicated that they are both public agency foresters and consulting foresters. Nearly all respondents (99 percent) possessed a four-year degree or higher in forestry or a related field. Respondents conducted a median of 12 sales per year with a median sale size of 50 acres.

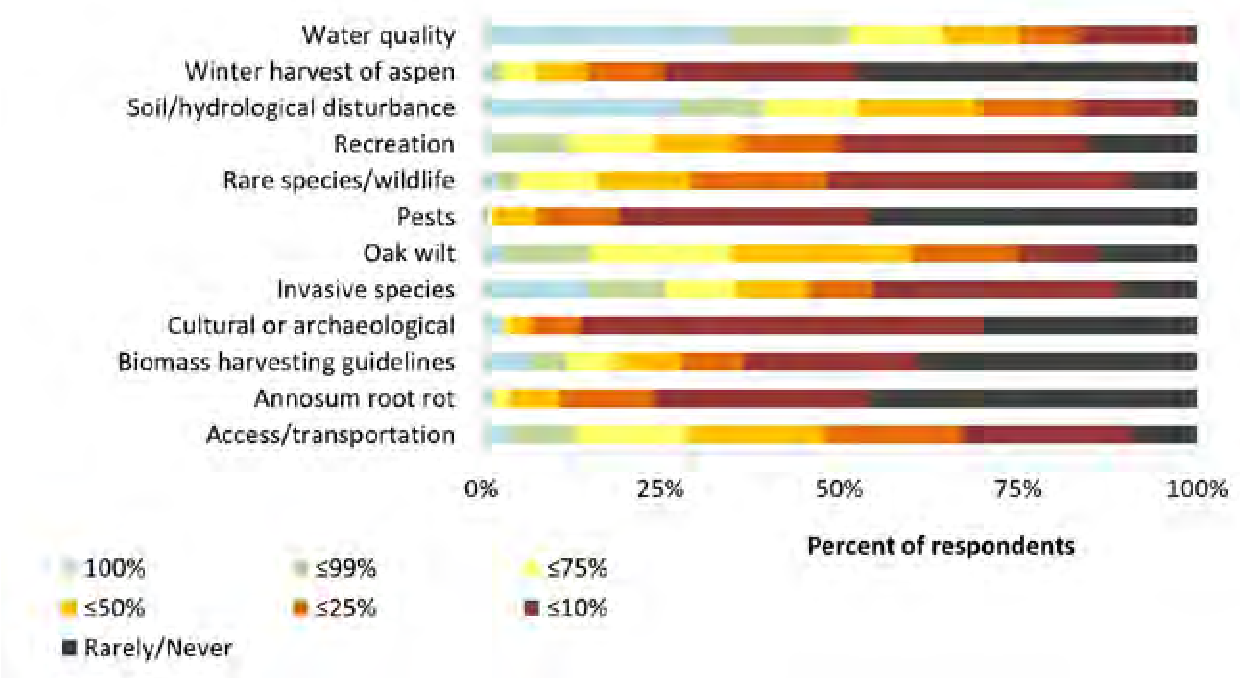
RESULTS

Application of forest management constraints

Forester survey responses showed significant variation in the frequency of application of particular forest management constraints in a typical year. Many foresters reported applying water quality best management practices (35 percent) and constraints to reduce soil disturbance such as rutting, compaction, and run off (25 percent) to every sale they design (Figure 4). Conversely, many foresters reported they rarely or never apply constraints requiring an aspen stand be harvested in the winter (48 percent), annosum root rot mitigation measures (46 percent), or biomass harvesting guidelines (39 percent) in a typical year. Other constraints we examined included oak wilt and rare species protection guidelines. Sixty percent of the forester survey respondents reported applying oak wilt constraints to at least a quarter of their sales. Seventy-one percent of the respondents reported applying rare species protection guidelines to protect to less than a quarter of their sales. Variation in the frequency with which foresters apply many of these constraints is likely related to the relative frequency of the associated concerns in the foresters' primary work area. Many forest management constraints are applied on the local level based on local conditions with a degree of professional discretion afforded to the administrating forester.

Fred Clark

Figure 4 Percent of timber harvests to which constraints are applied by foresters during a typical year.



In the timber professional survey, participants were asked if they develop timber sale prescriptions and set harvest terms in addition to their positions as loggers or wood purchasers. Nearly 90 percent indicated they do establish at least a few timber harvests in a typical year. Similar to the foresters, this group also showed great variation in the frequency with which they typically apply constraints to timber sales. This variation is highlighted by the fact that 12 percent of timber professionals indicated they apply water quality best management practices to every sale they design. At the same time, nearly half of the respondents indicated they apply these practices to less than ten percent of their sales. The most frequently applied forest management constraints were soil productivity (39 percent), forest health (37 percent), and recreation (37 percent) constraints, which were reported to be applied on at least half of the sales designed in a typical year. A large majority of timber professional survey respondents applied invasive species best management practices (73 percent) or constraints to protect threaten and endangered species (69 percent) on 10 percent or less of their sales. However, 12 percent of respondents indicated they used constraints to protect threatened and endangered species on over half of their sales. Nearly all timber professionals indicated they apply biomass constraints only very rarely, and no logger reported applying this constraint to more than ten percent of his or her sales.

Both forester and timber professional survey participants indicated a wide range of reasons they apply forest management constraints, but both groups identified professional judgment based on available science as the most important reason they applied most constraints (Tables 1 and 2).

Table 1 Percentage of forester survey respondents who indicated professional judgement was the reason for applying each constraint

Access/transportation constraints	58%
Annosum root rot constraints	48%
Biomass harvesting guidelines	35%
Cultural or archaeological constraints	27%
Invasive species best management practices	62%
Oak wilt constraints	68%
Pest restrictions (other than oak wilt or annosum)	54%
Rare species/wildlife constraints	37%
Recreation-related constraints	16%
Soil/hydrological disturbance constraints	79%
Requiring that an aspen stand be harvested in the winter	42%
Water quality best management practices	77%

Table 2 Percentage of timber professional survey respondents who indicated professional judgement was the reason for applying each constraint

Threatened and Endangered Species Protection	33%
Invasive Species Best Practices	54%
Water Quality Best Management Practices	69%
Protecting Soil Productivity	58%
Forest Health Protection	62%
Wisconsin Biomass Harvesting Guidelines	44%
Recreation Use Restrictions	30%

The only harvest constraint that foresters and timber professionals indicated they apply more frequently for regulatory reasons instead of professional judgement were threatened and endangered species constraints.

Conformance with Managed Forest Law and third-party forest certification mandatory practices were also frequently cited as reasons for applying constraints. Directives from the client or landowner motivated use of recreation based constraints but were not frequently cited as a significant influence on implementation of other constraints. Foresters and timber professionals indicated that the majority of landowners support the constraints they are applying (discussed further in *Landowner reactions to forest management constraints)*.

Operational constraints

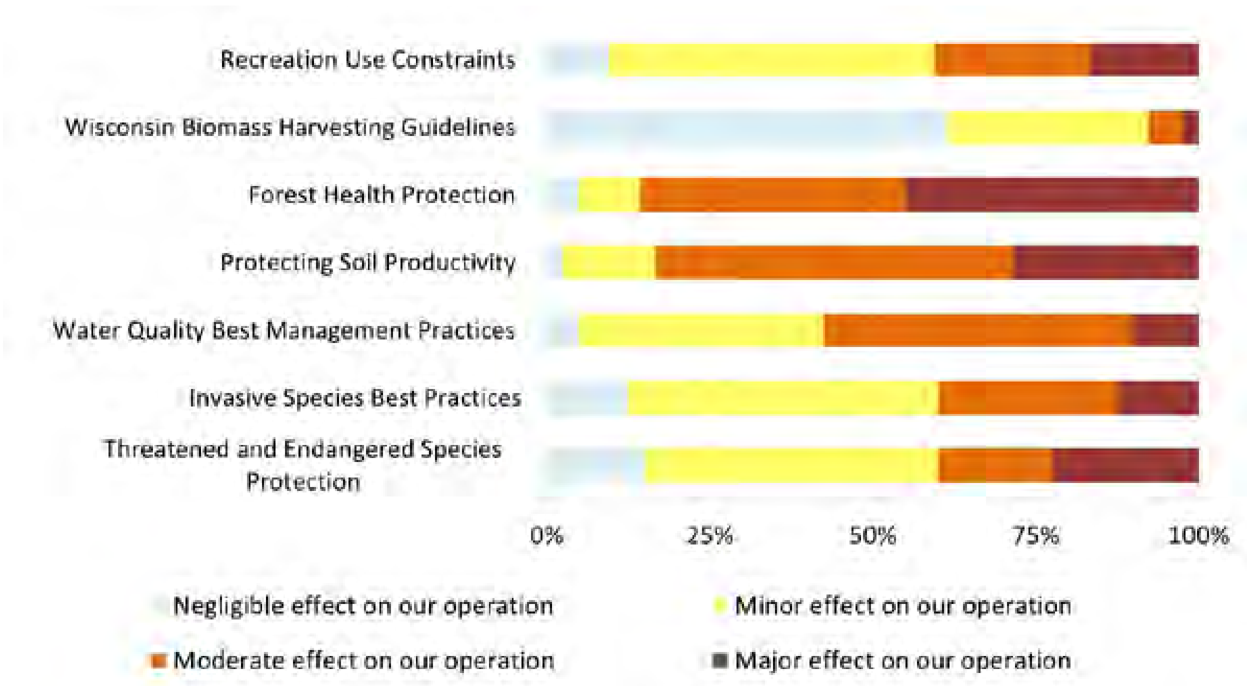
Timber professionals reported encountering harvest constraints on sales they purchase at about the same frequencies as the foresters reported applying them to their sales. Forty-one percent of timber professional survey respondents indicated that measures aimed at protecting soil productivity (i.e. seasonal constraints for sensitive soils and rutting limitations) and measures aimed at forest health protection (annosum root rot or oak wilt constraints) are imposed on at least half of their sales annually. These were also among the constraints foresters reported applying most frequently to sales they design. Additionally, constraints that foresters reported rarely applying were also rarely applied by timber professionals. For instance, timber professionals reported

Wisconsin biomass harvesting guidelines and threatened and endangered species protection measures are imposed on few of their sales and do not affect their operations in most years (Figure 5). Eighty three percent of respondents indicated that biomass harvesting guidelines affected ten percent or less of their sales in a typical year, and 64 percent indicated the same for threatened and endangered species.

The frequency with which a constraint is encountered and the size of its effect on a timber professional's operation are not necessarily related. For instance, one of the most commonly applied restrictions, protecting water quality, was reported to have a minor to moderate impact on a timber professional's operation when applied (Figure 5). Conversely, over 45 percent of the timber professionals indicated forest health protection measures aimed at reducing the impact of diseases such as annosum root rot or oak wilt have a major effect on their operations when applied.

When imposed, guidelines designed to protect soil productivity also had a major effect on operations for nearly 30 percent of timber professionals. In contrast, most respondents (62 percent) indicated biomass harvesting guidelines had a negligible impact.

Figure 5 Magnitude of impact timber professionals' perceptions of the impacts of harvest restrictions on their operations in a typical year

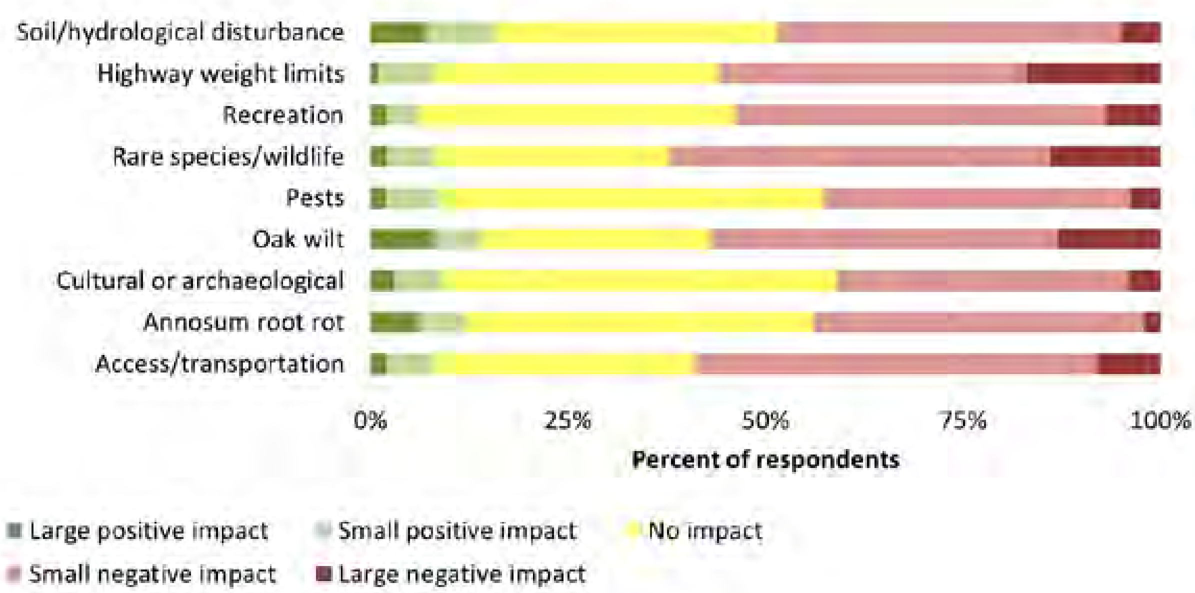


Several timber professional respondents provided additional information related to the effect of forest management constraints in open-ended responses. Although the open-end responses are not well suited to quantification, they provide an additional perspective on the constraints. Most of these open-ended responses identified oak wilt and spring operability constraints as the primary constraints that affect their businesses. Many of these responses also indicated the abundance of seasonally restricted wood placed excessive economic pressure on the unrestricted wood due to the need for year-round work. Other respondents indicated that they are forced to move their entire operation to counties with more operable conditions during spring/soft ground season. A few survey participants used this open-ended section as an opportunity to state their support for forest management constraints and indicated that if constraints for activities such as rutting were not required by the forester or landowner, they would impose such constraints upon themselves.

Figure 6 depicts the perceived magnitude of impact that constraints have on foresters' operations in a typical year. The majority of forester survey respondents indicated constraints had either no impact or a small negative impact on their organization in a typical year. Only oak wilt, rare species, and road weight restrictions had greater than ten percent of respondents indicate the constraint has a large negative impact on their organizations in a typical year, and some respondents indicated that every constraint had a positive impact on their organization. There was a dramatic difference in how foresters felt constraints impacted their organization based on their employment type. Public agency foresters reported a smaller average impact of constraints compared to family forest consultants, and foresters working for mills, loggers, or industrial timberland owners reported a higher average negative impact than family forest consultants for every constraint. Public agency foresters reported large negative impacts for their organization four percent of the time across all nine constraints in the survey. In contrast, independent forestry consultants and foresters working for mills, loggers, or industrial timberland owners indicated a large negative impact an average of 11 percent of the time across all nine constraints in the survey. This difference highlights the potential difference in the impact of constraint across employment type, which could be the focus of future research.

These results highlight the fact that like timber professionals, foresters and organizations are likely to feel the impact of forest management constraints in different ways. Only six percent of survey respondents indicated they get paid a commission for preparing and administering timber sales, while the rest were paid a salary, per hour rate, or a flat fee that did not fluctuate based on the final timber sale price.

Figure 6 Magnitude of impact that foresters perceive that constraints have on their operations in a typical year.

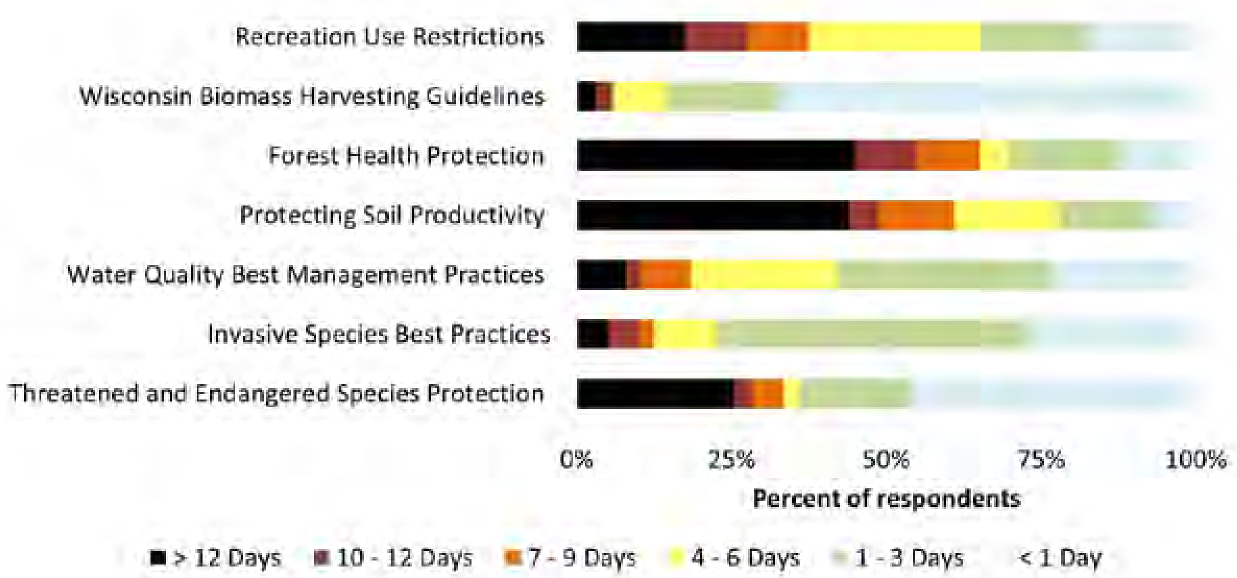


Seasonality of operational constraints

Timber professionals reported that forest management constraints impact their organizations in various ways. Many constraints such as rare species protection and recreation were identified as causing primarily seasonal restrictions. Constraints imposed to protect soil productivity and water quality created seasonal limitations on harvest periods and reduced on-site productivity. Others, such as constraints related to invasive species, are more likely to add direct costs to an operation instead of causing seasonal harvest limitations. The constraint timber professionals reported as having the largest impact on their operation when imposed, forest health protections, was identified as typically creating seasonal limitations, reducing on-site productivity, and adding to the direct cost of an operation.

A large percentage of the timber professional respondents indicated that constraints associated with protecting forest health (45 percent) and soil productivity (44 percent) commonly cost an operation more than 12 days per year (Figure 7). Meanwhile, biomass harvesting guidelines (68 percent) and rare species constraints (46 percent) cost many operators less than one day per year. Although most timber professionals indicated they rarely have sales with constraints aimed at protecting rare species, and these constraints cost many operations less than one day per year, it is worth noting that for about 25 percent of timber professionals, these constraints can cause 12 days or more of lost production. So while the frequency of rare species restrictions is low, the impact can be large when such restrictions are applied. Timber professionals who identified as loggers showed similar patterns in their responses to those identified as wood purchasers; however, loggers tended to have lower estimates of lost work days than wood purchasers.

Figure 7 Number of production days lost due to constraints in a typical year as reported by timber professionals.



Impact of operational constraints on timber price

On average, timber professionals estimated their cost of production was $42 (SD 11.9) per cord. This is only 15 percent less than the average price paid for a cord equivalent on public lands in 2014, which was $50 (WIDNR 2015). The median estimate from survey respondents of total direct cost (fuel, wages) to mobilize one logging crew (processor / forwarder) on a typical job within 50 miles was $1,000. With these narrow margins, the impacts of operational constraints on timber price can have a significant impact on operators.

Timber professionals and foresters estimated similar costs for constraints. Most forester survey respondents indicated seasonal harvesting constraints reduce the stumpage price received on timber sales either significantly (31 percent) or slightly (53 percent). Twelve percent of foresters indicated they typically do not see any change in stumpage prices on their sales whether they apply constraints or not. Of those who did report a price change related to forest management constraints, about half indicated they see some sales fail to sell due to seasonal constraints (typically less than one per year).

Similarly to timber professionals, foresters reported the cost associated with forest management constraints was not standard for all restrictions; some have a larger impact on the sale price than others (Figure 8). Respondents indicated that access constraints and winter-only harvesting constraints had the biggest impact on price. Most respondents felt constraints to protect soils (53 percent), cultural resources (64 percent), or to reduce pest impacts (52 percent) had no impact on sale price (Figure 8). When asked what factors impact stumpage price in Wisconsin, forester survey respondents rated the health of Wisconsin timber markets as the most important factor. Foresters rated government regulations and seasonal timber harvesting constraints the second and third lowest in importance, respectively (Table 3).

Figure 8 Foresters estimates of percent price change due to constraints

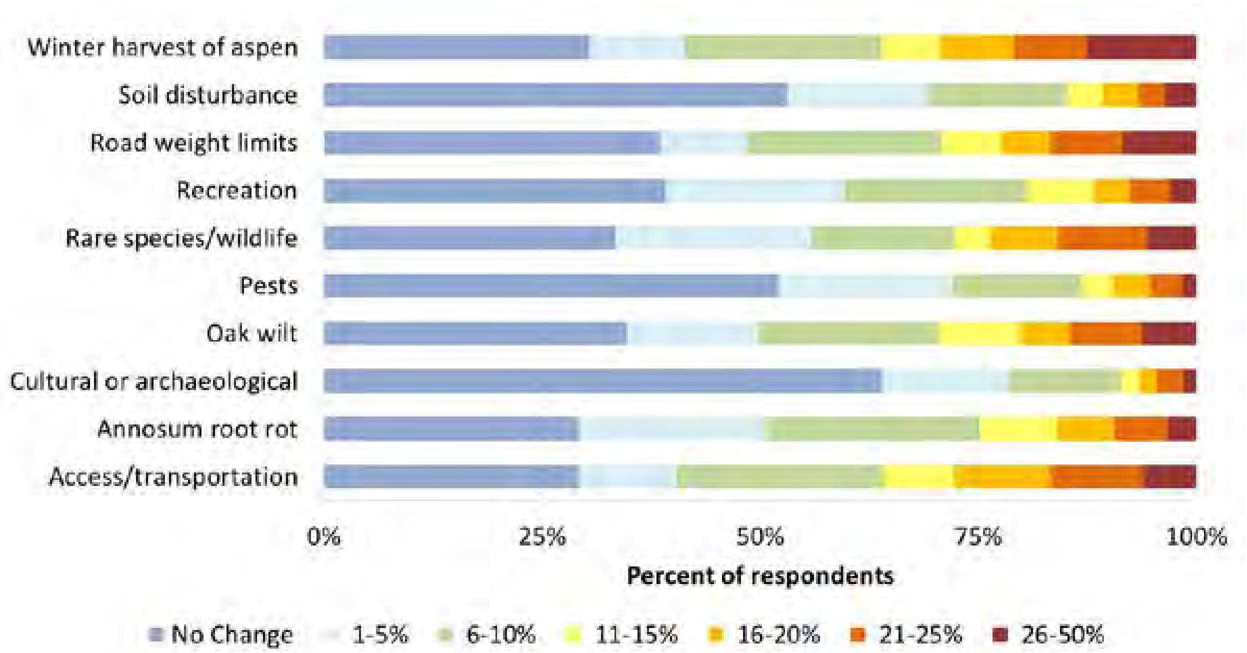


Table 3 The average rating by foresters of factors affecting stumpage price on their timber sales in a typical year

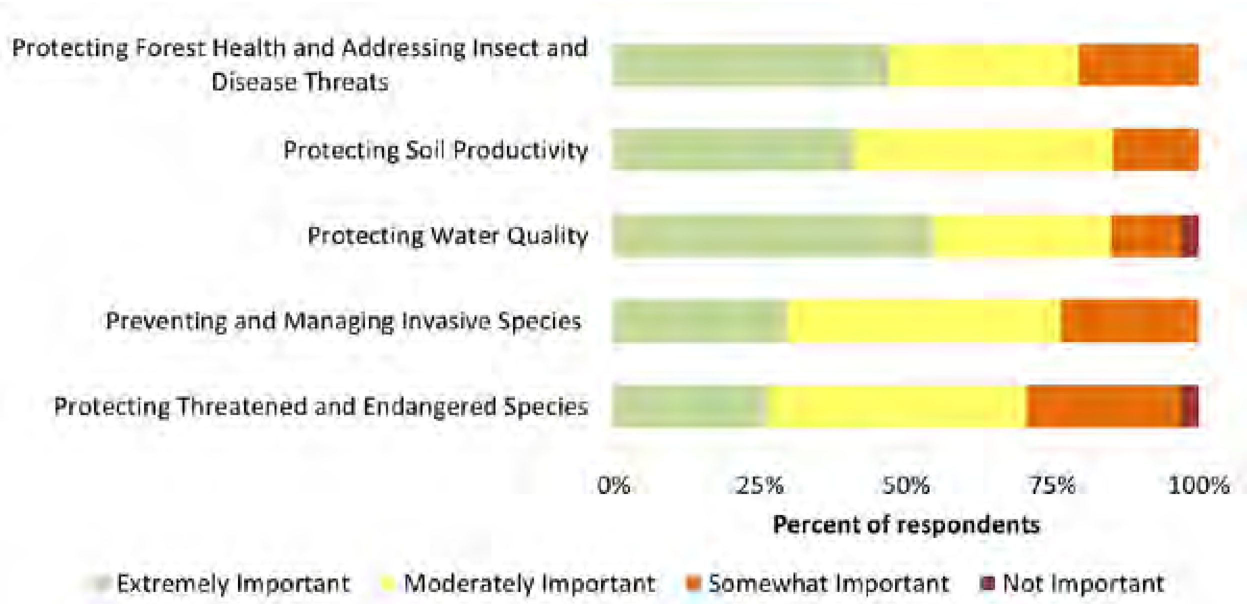
Factors Affecting Stumpage Price	Average Rating
Health of Wisconsin timber markets	4.6
Proximity of timber sale to mills	4.3
Species of timber for sale	4.2
Competition between loggers	4.1
Timber quality	4.1
Size of the timber sale	4.0
Health of the United States' economy	3.9
Seasonal timber harvesting restrictions imposed	3.8
Government regulations	3.5
Silvicultural prescription (i.e. thinning, clearcut, etc.)	3.3

Average rating scale was developed using 1=not important, 2=of little importance, 3=moderately important, 4=important, 5=very important

Timber professional and forester opinions about harvesting constraints

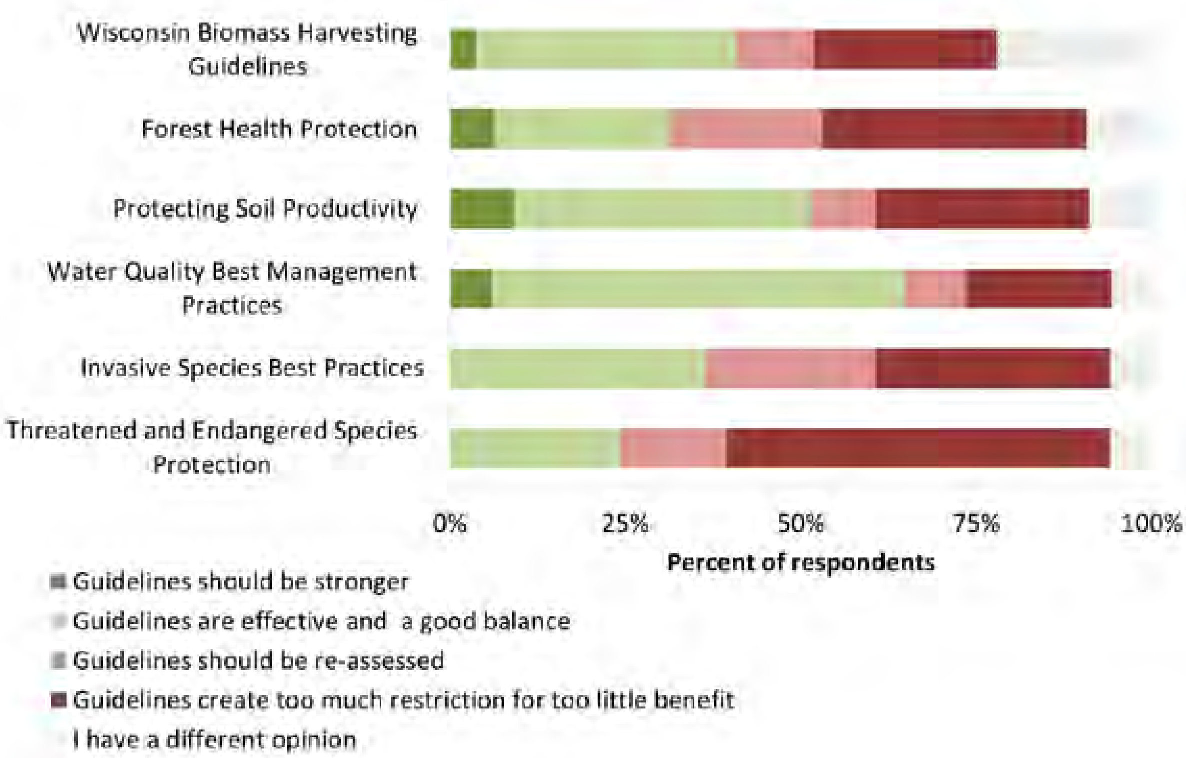
Over 70 percent of timber professionals indicated they believed protecting forest resources and values was either extremely or moderately important (Figure 9). Water quality and forest health were viewed as most important with 85 percent of respondents indicating they were at least moderately important to protect. While most respondents indicated protection of resources was important, protection of threatened and endangered species received the fewest extremely (26 percent) or moderately (44 percent) important ratings. One respondent added a comment that seems to sum up most timber professionals feelings: "I am a tree hugger and believe that most loggers are. I hope to have a beautiful forest for future generations, but we need to find a good balance."

Figure 9 Importance of protecting forest values and resources



While results indicated overwhelming support for the protection of forest values and resources, timber professionals' opinions about the current guidelines and recommendations were mixed. The majority of respondents (59 percent) felt the current guidelines are effective and are a good balance between short-term and long-term needs for water quality (Figure 10). The majority of timber professionals (52 percent) also supported the existing or stronger guidelines for soil productivity. However, nearly 70 percent of the survey respondents felt the current threatened and endangered species avoidance guidelines create too much constraint for too little benefit or that they should be re-assessed. Nearly 60 percent of timber professionals felt the same way about forest health constraints and invasive species best practices. In the associated open-ended section, one timber professional indicated the effectiveness answer often depends on the situation or implementation. For instance, this respondent felt annosum recommendations are effective, but the requirement for a pesticide applicators license make it onerous to implement.

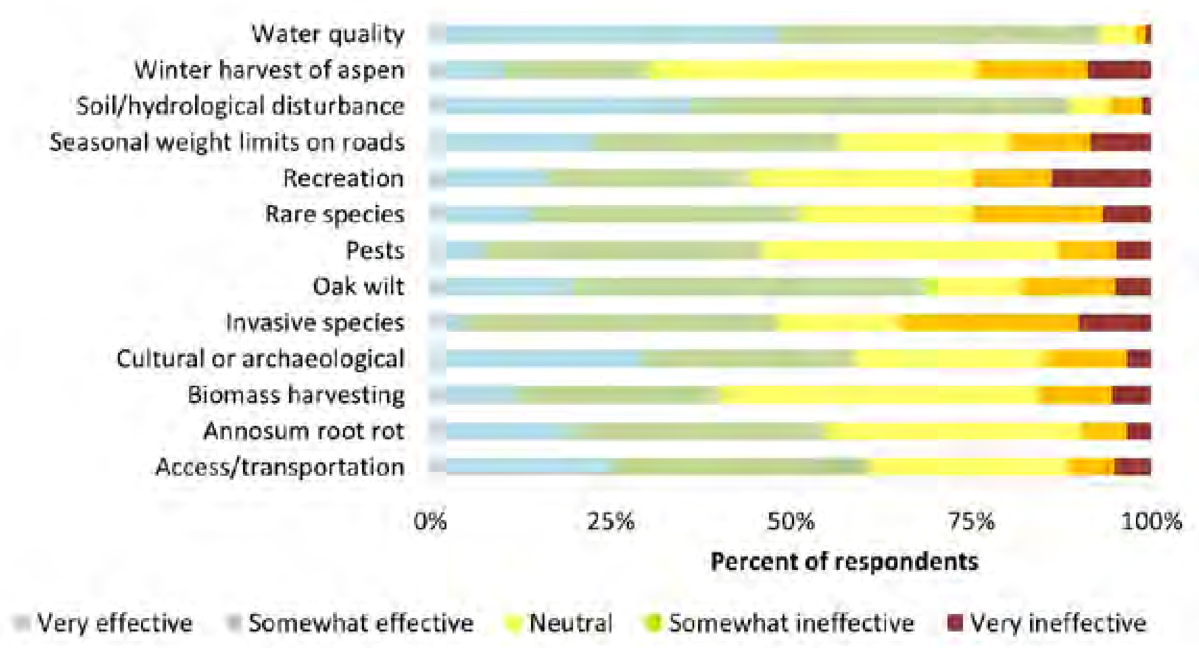
Figure 10 Foresters' opinions of the efficacy of current guidelines and recommendations



Respondents to the forester survey rated the current practices related to water quality and soil disturbance as the most effective at protecting forest health, productivity, and other ecosystem values in the long-term (Figure 11). In addition, more than half of respondents rated seasonal weight limits (57 percent), rare species and wildlife protections (51 percent), oak wilt guidelines (69 percent), cultural constraints (59 percent), Annosum recommendations (55 percent), and access constraints (61 percent) as at least somewhat effective. Recreation-based forest management constraints received the most "very ineffective" ratings; nearly 14 percent of the foresters believe these do not accomplish the stated objective.

Overall, Wisconsin foresters who participated in this study largely agreed (70 percent) with a statement that seasonal timber harvesting constraints have increased the cost of delivered wood to Wisconsin mills; however, the majority of foresters also indicated that seasonal timber harvesting constraints, as currently applied, benefit Wisconsin's forest landowners (67 percent) and industry (46 percent). Over three quarters of the forester survey respondents indicated that, in their professional judgment, the benefits outweigh the costs associated with implementation of soil compaction/rutting constrains and water quality BMPs. Nearly that proportion of the respondents (64 percent) indicated the benefits of oak wilt constraints outweighed costs, with over forty percent indicating the benefits far exceed the costs. Rare species and recreation-related constraints were less widely supported; over half of the foresters surveyed indicated they believe the costs associated with these restrictions outweigh the benefits and should be re-evaluated.

Figure 11 Foresters' rating of the effectiveness of constraints at protecting forest health, productivity, and other ecosystem values

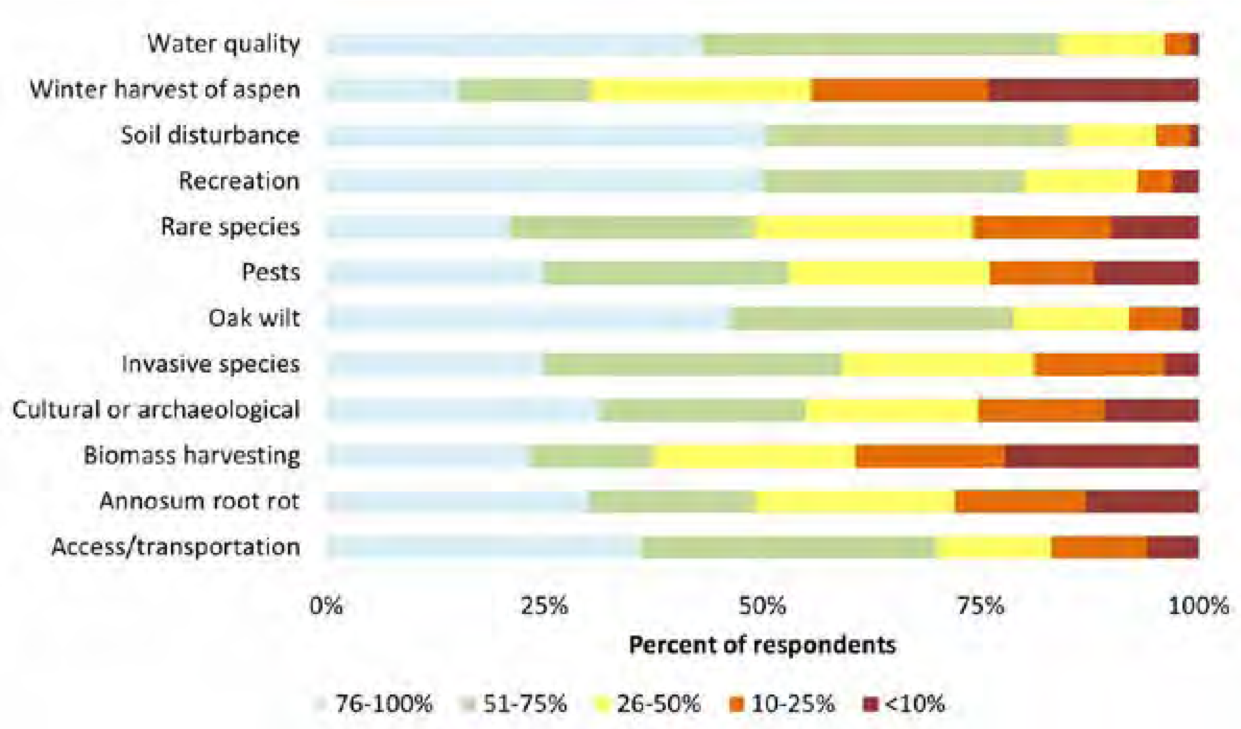


Landowner reactions to forest management constraints

Foresters indicated that many of the landowners they work with are supportive of the constraints they apply (Figure 12). According to the foresters, constraints geared towards protecting soil productivity or water quality, slowing the spread of oak wilt, and supporting recreational values are most commonly supported by landowners. According to foresters, Wisconsin biomass harvesting constraints and requirements to harvest aspen in the winter have the lowest support among Wisconsin landowners.

Timber professionals who reported that they at least occasionally set up timber sales indicated that many of the landowners they work with are also typically supportive of the constraints they apply. These respondents indicated landowners are most supportive of constraints to protect soil productivity (69 percent) but a large number of landowners also support constraints to protect water quality (59 percent), and recreation (59 percent). These timber professionals believe that fewer than half of landowners support constraints to protect forest health (48 percent) and rare species (46 percent). Thirty-two percent of timber professionals thought that a small percentage (less than 10 percent) of the landowners they work with support biomass harvesting guidelines and 35 percent thought a small percentage of landowners support rare species protections.

Figure 12 Foresters' opinion about the support of landowners for constraints



DISCUSSION

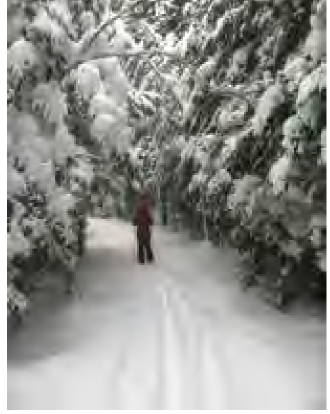
The survey results from the 377 foresters and the 55 timber professionals show that the impacts of harvesting vary significantly in frequency, magnitude, type of effect, and impacted season based on the kind of constraint. Surveys of both timber professionals and foresters reveal they often apply harvesting constraints to the timber sales they set up, and they most typically apply constraints designed to protect water quality and forest productivity. They apply other constraints such as requirements to harvest aspen stands in the winter, annosum root rot mitigation measures, or biomass harvesting guidelines less often. A large majority of foresters indicated they apply wildlife or rare species guidelines to less than 25 percent of their sales. For more detailed description of the responses, please see the preceding discussion of the survey results.

Overall, professional judgment based on available science was the most important reason foresters and timber professionals applied constraints. State endangered species regulations were the main reason they applied constraints specifically to protect threatened and endangered species. Wisconsin's Managed Forest Law and County Forest Law are also a source of mandatory practices, while third-party forest certification standards are viewed as a de-facto requirements to adopt constraints that would otherwise be categorized as voluntary guidelines on water quality best management practices and forest health protection.

The majority of forester survey respondents indicated that forest management constraints had either no impact or a small negative impact on their organization (see the previous section, *Operational Constraints*, for more detail). Similarly, most timber professionals reported negligible or minor impacts for most constraints, but constraints to protect soil productivity and forest health had moderate to major impacts on logging operations. The majority of respondents to the forester survey said that seasonal timber harvesting constraints have increased the cost of delivered wood to Wisconsin mills, and more than 80 percent of forester survey respondents indicated seasonal harvesting constraints reduce the stumpage price received on timber sales. Timber professionals said that constraints associated with forest health protection and protecting soil productivity can commonly cost a logging business more than 12 days per year.

Even with the additional costs, the majority of forester and timber professional respondents supported existing or stronger guidelines for water quality and soil productivity. On the other hand, nearly 70 percent of timber professionals felt the current threatened and endangered species avoidance guidelines create too much restriction for too little benefit and should be re-assessed. Timber professionals and foresters both indicated that many of the landowners they work with support the constraints being applied. However, it is important to note that we did not survey landowners directly and so future research could provide more detail on their opinions. In general, the support for constraints may be due in part to the duration of their use. In other words, constraints that have been in place for a longer time may receive more support because people have heard a message about their importance (such as water quality BMP's) and have had time to become used to them.

Fred Clark



Fred Clark (left, right), Mike Lynch (middle)

Some of the constraints that have major impacts are also those that forestry professionals feel are the most important for protecting forest health, forest productivity, and other ecosystem values. For example, constraints to protect soil productivity often cause major impacts, but are supported by the majority of the timber professionals we surveyed. Many timber professionals indicated they would place these constraints upon themselves based on professional judgment and a commitment to the resources even if they were not imposed by the landowner, forester, or oversight body (see Tables 1 and 2 for more detail).

Summary

- There is significant variation in how often constraints are applied to timber harvests and magnitude of the impact.
- Foresters rated the current practices related to water quality and soil disturbance as the most effective at protecting forests.
- Foresters rated government regulations and seasonal timber harvesting constraints the second and third lowest in importance.
- The majority of forester survey respondents indicated that forest management constraints had either ‘no impact’ or ‘small negative impact’ on their organization. Similarly, most timber professionals reported negligible or minor impacts for most constraints, but constraints to protect soil productivity and forest health had moderate to major impacts on logging operations.
- The majority of timber professional indicated that constraints associated with forest health and soil productivity commonly cost an operation more than 12 days per year.
- Timber professionals indicated they rarely have sales with constraints aimed at protecting rare species but when they do these constraints can cause 12 days or more of lost production.
- Overall, professional judgment based on available science was the most important reason foresters and timber professionals applied constraints.
- Even with the additional costs, the majority of forester and timber professional respondents supported guidelines for water quality and soil productivity.
- Survey respondents also indicated that many of the landowners they work with support forest management constraints, particularly water quality, soil productivity, and recreation constraints.

ASSESSMENT OF ECONOMIC EFFECTS

The second phase of the project assessed the economic impacts of the forest management constraints on the state of Wisconsin. The economic impacts of constraints are an important consideration because Wisconsin's forest industry represents $23 billion (2012) in direct outputs, and $30 billion of indirect outputs such as spending at other area businesses by the forest industry (WIDNR 2012).

METHODS

We used IMPLAN (IMpact analysis for PLANning, www.implan.com) version 3.1, an input-output modeling software for the economic modeling (IMPLAN, 2015). IMPLAN is a mathematical input-output model that employs a matrix representation of the region's economy to predict the effect of changes in one industry on the others and by consumers, government, and suppliers on the economy. The IMPLAN database contains county, state, zip code, and federal economic statistics, which are specialized by region, not estimated from national averages. Input-output economics has been used to study regional economies within a nation and has been used widely as a tool for regional economic planning and studies of the forest industry (e.g. BBER 2012, 2013, Dahal et al. 2015). In addition, a main use of input-output analysis is to show the economic impact of a potential change or event on a particular industry or group of industries. We used input-output analysis as the primary economic analysis tool in this study.

We selected five focal areas to incorporate a diversity of land ownership (public and private), regional economies, and forest types. These regions are based on the Forest Inventory and Analysis (FIA) survey units for Wisconsin (Figure 13). Based on the most recent IMPLAN data, more than 70 percent of the 3.5 million jobs in the state were located in the southeastern focal area. The southeastern portion of the state includes the greatest number of counties as well as the metropolitan areas of both Madison and Milwaukee.

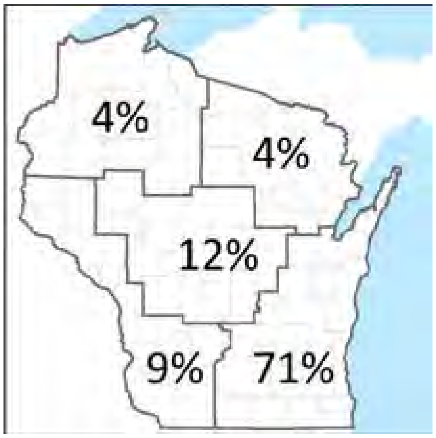


Figure 13 Employment in All Industries (IMPLAN, 2015)

We supplemented the IMPLAN data with additional case study data from timber professionals and foresters across the state. As discussed in the section, *Assessment of Constraints through Harvest Case Studies*, we used detailed sale-level data from the Wisconsin Board of Commissioners of Public Lands, Marathon County, The Forestland Group, the Kickapoo Woods Cooperative, and other partners to derive information on timber sale prices. The harvest case study data also helped describe the implications of forest management constraints (e.g. delayed harvests, reduced harvest area, or increased sale administration costs). We followed up with additional interviews as necessary to ensure the accuracy of the harvest case study data and to clarify assumptions required to extrapolate from survey results to the state level. Another source of information for the economic modeling was the surveys conducted of foresters and timber professionals in Wisconsin, which are described above in the section, *Forester and Timber Professional Survey Results*.

Defining and quantifying the forest industry is challenging because it is so diverse and extends from primary producers through logging to forest products manufacturing. We identified sectors within IMPLAN related to the forest industry and grouped them into three parts: Primary Forest Products Manufacturing, Secondary Forest Products Manufacturing, and Forestry and Logging (Table 4). We selected the sectors and groups based on similar economic studies of the forest industry in the Lake States (BBER 2013). All models are imperfect reflections of reality; our model excluded potential impacts on paper or lumber mills. The inclusion of these sectors would yield different results. Our economic impact analysis models changes to timber professionals and land-owners, but this table provides context on the numbers of jobs in each focal area, and how the results compare to the industry as a whole.

Table 4. Employment in Forestry-Related Sectors, State of Wisconsin, 2013 (IMPLAN 2015)

Primary Forest Products Manufacturing	***Employment***
Sawmills	2,011
Veneer and plywood manufacturing	1,547
Reconstituted wood product manufacturing	471
Paper mills	11,849
Secondary Forest Products Manufacturing	
Wood preservation	177
Engineered wood member and truss manufacturing	860
Wood windows and doors and millwork manufacturing	5,403
Cut stock, resawing lumber, and planing	294
Other millwork, including flooring	2,277
Wood container and pallet manufacturing	2,736
Prefabricated wood building manufacturing	1,026
All other miscellaneous wood product manufacturing	1,550
Pulp mills	35
Paperboard mills	709
Paperboard container manufacturing	5,597
Paper bag and coated and treated paper manufacturing	6,554
Stationery product manufacturing	1,297
Sanitary paper product manufacturing	3,484
All other converted paper product manufacturing	1,522
Wood kitchen cabinet and countertop manufacturing	2,468
Nonupholstered wood household furniture manufacturing	4,221
Wood office furniture manufacturing	238
Custom architectural woodwork and millwork	438
Showcase, partition, shelving, and locker manufacturing	1,936
Forestry and Logging	
Forestry, forest products, and timber tract production	89
Commercial logging	3,883
Support activities for agriculture and forestry (only 2.0% applies to forestry)	203
TOTAL Forestry Industry	**62,872**

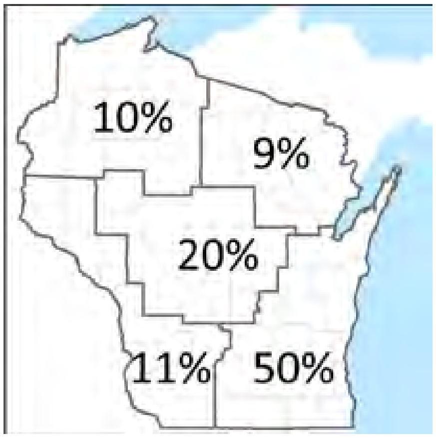


Figure 14 Employment in Forestry-Related Sectors

The forestry industry as a whole employed more than 62,000 workers in the state in 2013. The largest sectors in terms of employment were Paper Mills (11,800 workers), Paper Bag and Coated and Treated Paper Manufacturing (6,500 workers) and Paperboard Container Manufacturing (5,600 workers). The Logging sector, which is the primary focus of this analysis, employed approximately 3,900 individuals statewide in 2013, the sixth highest employer among those sectors included in Table 4. Employment in forestry-related sectors is more evenly distributed across the state than overall employment (Figure 14). About half of the employment in the forestry-related sectors is in southeastern Wisconsin compared to 71 percent of total employment. The large share of forestry-related employment in the southeastern region is driven by the location of secondary forest products manufacturing in that region. The percentage of forest industry employment in the Northeastern and Northwestern focal areas is more than twice the percentage of total employment in those regions.

We used IMPLAN sector 16, Commercial Logging, for modeling impacts related to the logging industry. The commercial logging sector includes: cutting and transporting timber, cutting timber, log harvesting, logging, pulpwood logging camps, rough wood manufacturing, stump removing in the field, timber piling, timber pole cutting, tree chipping in the field, and wood chipping in the field. Our team analyzed the results of the timber sales case study data to estimate the potential increase in production that the logging industry would realize if seasonal harvest restrictions resulted in an additional 30 days (one month) of operability.

We focused on a change of one month for several reasons. First, some constraints such as annosum or invasive plant management recommendations do not prohibit harvest, but instead increase operational costs. Second, in both survey results and during our listening sessions, foresters and timber professionals identified seasonal oak wilt and frozen ground constraints as particularly important. Frozen ground constraints limit logging to varying degrees year to year as a result of weather conditions. On average, the period of frozen ground has been shortened by between two to three weeks between 1948 and 2012 in Wisconsin (Rittenhouse and Rissman 2015). Oak wilt guidelines are a seasonally variable constraint modulated by factors such as warm spring temperatures or low risk tolerance of landowners.

The results of the case studies showed that, on average, timber harvest contracts had 6.5 months of allowable operation in a given year due to forest management constraints. Only eight of the 170 harvest records analyzed allowed 12-months of operation. In a scenario wherein all 170 sales allow operation during July, the average number of operable months increases to 7.1 months. Similarly, if temperatures allowed for an additional month of frozen ground conditions the average number of operable months would be 7.4. This suggests that, without any constraints in July, timber professionals could potentially increase production levels by about nine percent. In the open-end response sections of our survey, some timber professionals indicated that they frequently chose to not even enter a bid on seasonally restricted sales. At the same time, many timber professionals stated in the listening sessions that they are able to operate for twelve months out of the year, despite constraints, by scheduling work based on constraints or employing fewer workers. This would suggest that the true increase in production would be less than nine percent, as most operations are not necessarily fully idle during the months with constraints. Therefore, we assumed direct effects would range somewhere between five and ten percent of increased operations for the industry.

Other modelling scenarios are possible, and with additional data, future research could expand the results presented here by examining specific proposed changes to constraints. Similarly, as described in more detail in the section *Modeled economic impacts to private landowners*, we did not include direct assessment of impacts to landowners. Another sector that could be the focus of future economic impact assessment is the forest product sector, i.e., pulp and paper mills and sawmills. While beyond the scope of this study, an assessment of the impact of forest management constraints on mills would require detailed, and often propriety, price data on wood supplies. Such an

assessment would have to be able to factor out important market drivers such as overall wood products demand and product price competition both within and beyond Wisconsin. For instance, other studies have demonstrated the ability of forest products producers to pass forest management costs on to consumers (Murray and Wear 1998, Wear and Murray 2004).

RESULTS

Modeled economic impacts to timber professionals

To show the potential range of economic impacts, a sensitivity analysis was conducted with both a five and ten percent increase in production for each focal area. Table 5 shows, for each focal area, the total output in the industry in 2013 as well as the direct impacts on the logging sector associated with a five and ten percent increase in production. We used these impacts for developing the economic models.

Figure 15 Logging sector output in 2013 in millions of dollars

Table 5. Output Levels for Commercial Logging Sector and Estimates for Modeling Increased Production Levels in millions of dollars

Region	*2013 Output (Logging sector)*	*5% increase*	*10% increase*
Central	$87	$4.4	$8.7
Northeastern	$73	$3.6	$7.3
Northwestern	$107	$5.3	$11
Southeastern	$16	$0.8	$1.6
Southwestern	$39	$1.9	$3.9
Wisconsin	$322	$16	$32

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The timber harvests by region help to put the output from the logging sector in context. Based on average annual removals between 2009 and 2014 (WIDNR 2015) and assuming 80 cubic foot of wood is equivalent to one cord, the wood removed in Wisconsin is worth approximately $214.6 million dollars. Northern Wisconsin makes up two thirds of this total value of wood removed (Figure 16). For south and central Wisconsin, logging sector output is approximately twice the value of timber removed. In Northern Wisconsin, the value of wood removed appears closer to the logging sector output value from IMPLAN.

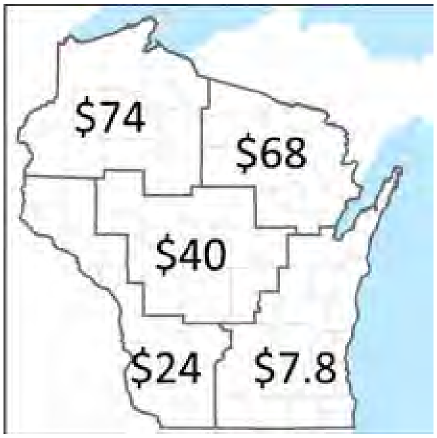

Figure 16 Value in millions of dollars of wood removed

Modeled economic impacts to private landowners

Determining the appropriate sector and direct impacts for modeling the economic effects to landowners proved more difficult. A new study by Steigerwaldt Land Services (2015) indicates that 60 percent of the harvest volume in Wisconsin originated from family or single, small private ownership; 30 percent from public lands; and two percent from Native American ownership. Only eight percent of Wisconsin's forest lands are owned by private forest industry. Therefore, depending on the landowner, economic impacts might be felt in a variety of areas including local households, the government sector, or private sectors related to the forestry industry. Much of our analysis focused on determining the appropriate sector for each type of landowner and the extent to which landowners would spend the additional income they receive from relaxed constraints throughout the broader economy.

A careful evaluation of some of the largest private land owners within Wisconsin's Managed Forest Law (MFL) and Forest Crop Law (FCL) programs found very little consistency between their industry classifications. We were able to find industry classifications for half of the large account MFL & FCL landowners. Of those, the most common classification was Support Activities for Forestry, but only five of the 87 landowners classified themselves in that industry (Table 6). The large variation in industry classifications suggests that most of the large private forest landowners are not actively engaged in forestry operations and instead use forest land as investment to support their primary business. Hence large private landowners may be affected by changes in income from timber sales, but changes in income as a result of changes to forest management constraints would not likely impact their daily operations. In other words, our team assumed no intermediate expenditures or industry production on the part of the large private landowners. Instead, we expect they would see only an increase in investment income or net income at the corporate level.

Table 6. Industry Classifications for Large Account Landowners

NAICS Code	Description	Landowner Count
115310	Support activities for forestry	5
321113	Sawmills	4
113310	Logging	3
237210	Land subdivision	3
423310	Lumber, plywood, millwork, and wood panel merchant wholesalers	3
523930	Investment advice	3
561730	Landscaping services	3
423320	Brick, stone, and related construction material merchant wholesalers	2
444190	Other building materials dealers	2
114210	Hunting and trapping	1
238990	All other specialty trade contractors	1
321912	Cut stock, re-sawing lumber, and planning	1
322219	Other paperboard container manufacturing	1
332312	Fabricated structural metal manufacturing	1
333318	Other commercial and service industry machinery manufacturing	1
488510	Freight transportation arrangement	1
523110	Investment banking & securities dealing	1
531210	Offices of real estate agents and brokers	1
541990	All other professional, scientific, and technical services	1
561910	Packaging and labeling services	1
721120	Casino hotels	1
813910	Business associations	1

For small landowners, annual income derived from timber harvest is typically small. Based on the national woodland owner survey, 83 percent of landowners with more than 10 acres derived no annual income from their forest and woodland (Butler et al. 2015). Only eight percent of landowners derive more than four percent of their income from their forest or woodland. In Wisconsin, the production of sawlogs, pulpwood or other timber products is very important or important to only five percent of families who own forestland (Butler et al. 2016).

Timber income for family forest owners is episodic or infrequent, and anecdotally, such occasional income is often spent on large investments such as health care, college, or retirement. In general, one-time income such as from tax returns or timber income is not typically spent in a traditional household spending pattern (Thaler 1990, Shapiro and Slemrod 2009). Because of the very small annual impact of timber income for small landowners and the non-traditional spending patterns of this type of income, we opted not to include a constraint impact for small forest landowners. Similarly, we excluded from the model potential changes in income to government landowners from constraints because there is little connection between revenue and spending. In other words, money received by governments is not connected to where and how the money is spent.

In summary, our research found that Wisconsin's forest landowners are a diverse group that includes small private households, a wide range of industry sectors, and various levels of government. It is impossible to characterize the income received by this wide variety of owner profiles landowners in any single method because in many cases it may not a primary source of income. For this reason, we did not attempt to model the economic impacts resulting from changes to forest management constraints for landowners.

Modeled economic impacts to forest products industry

These results include the direct, indirect, and induced economic impacts of forest management constraints in each of the geographic focal areas, as well as the total impacts for the state of Wisconsin, measured in employment, output, and value added.

Our analysis estimates that changes in forest harvesting constraints to allow for one additional month of timber harvest (or a five to ten percent increase in production) would generate between 358 and 717 Wisconsin jobs (Table 7), almost half of them in northern Wisconsin. It is important to note that the job estimate includes temporary or part-time jobs and is not an estimate of full-time equivalent jobs. In fact, dividing the labor income by the estimated employment yields approximately $35,000 per job, which is significantly lower than the average annual earnings in Wisconsin of nearly $54,000 (U.S. Census Bureau 2016). More than half of the jobs are estimated to come directly from the Commercial Logging sector itself, but other industries are also predicted to have increased temporary, part-time, or full-time employment (Table 7). One important point to note when considering the impacted sectors is that IMPLAN is a backward-linkage model. In other words, IMPLAN looks backward through the supply chain. Therefore, the results show impacts to industries that produce the intermediate inputs required to support the commercial logging industry. The results will not show any forward linkage effects such as increasing sawmill output.

Table 7. Effect of Employment as a Result of Tested Scenarios in the Top Ten Sectors, State of Wisconsin

Description	5%	10%
Commercial logging	193	386
All other crop farming	74	149
Support activities for agriculture and forestry	11	22
Wholesale trade	6	11
Hospitals	4	8
Full-service restaurants	4	7
Limited-service restaurants	3	6
Real estate	3	6
Truck transportation	3	5
Retail – General merchandise stores	2	4
Total	**358**	**717**

The model estimates that one additional month of operations for the logging industry would likely add between $13 million and $26 million in employee wages and benefits in the state of Wisconsin (Table 8). The increase in employee compensation includes wages, benefits, and proprietor income. The last column, Output, is the value of all local production required to sustain activities. An increase in commercial logging activity is predicted to increase total Output between $31.5 million and $63 million throughout the state, in combined direct, indirect and induced spending effects.

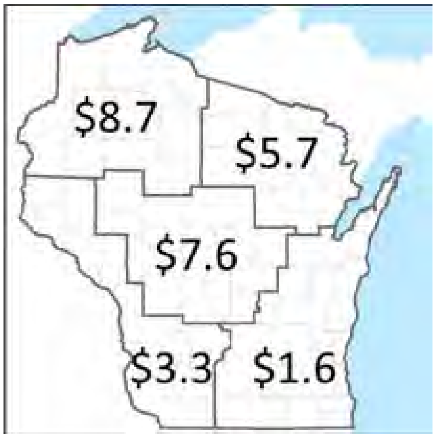

Figure 17 Economic impacts resulting from a 5% increase production in the logging sector

Table 8. Economic Impacts Resulting from a 5% to 10% Increased Production in Commercial Logging Sector (millions of dollars)

Total Effects	Employment	Labor Income	Output
Northeastern	68 to 136	$2.3 to $4.6	$5.7 to $11
Northwestern	104 to 208	$3.4 to $6.9	$8.7 to $17
Central	85 to 169	$3.3 to $6.5	$7.6 to $15
Southwestern	40 to 80	$1.3 to $2.7	$3.3 to $6.5
Southeastern	20 to 40	$0.6 to $1.2	$1.6 to $3.3
Wisconsin	358 to 717	$13 to $26	$32 to $63

The total effects are a combination of direct, indirect, and induced effects (Table 9). The direct effect of a five percent increase in logging production equates to between $16 million and $32 million in increased output and between an additional 193 to 386 employees for the state. The Indirect Effect category represents increased spending between commercial, government, and service industries as a result of the direct effects (between $7.1 million and $14 in increased industry spending and between 102 to 204 supported jobs). The Induced Effect measures the amount of increased spending by residential households as a result of the direct effects (between $8.3 million to $17 million in new household spending and between 64 to 127 supported jobs). In addition, we estimate that a five to ten percent increase in production in the commercial logging industry would increase the Value Added impact between $17 million and $34 million throughout the state. Value Added represents the contribution to GDP made by an individual producer, industry, or sector.

Table 9. Detailed Impacts Resulting from a 5% to 10% Increased Production in Commercial Logging Sector (in millions of dollars)

Impact Type	Employment	Labor Income	Value Added	Output
Direct Effect	193 to 386	$7.5 to $15	$8.3 to $17	$16 to $32
Indirect Effect	102 to 204	$2.6 to $5.2	$4.1 to $8.3	$7.1 to $14
Induced Effect	64 to 127	$2.7 to $5.4	$4.7 to $9.5	$8.3 to $17
Total Effect	358 to 717	$13 to $26	$17 to $34	$32 to $63

The largest impacts from the modeled increase in logging production are seen in the northwest region of the state, with between $5.3 million and $10.7 million in increased direct spending and between 65 and 130 new direct jobs in the commercial logging industry as a result of the five to ten percent increase in production. These direct effects result in total output effects between $8.6 million and $17.3 million with a total employment effects of 104 to 208 new jobs. The other regions are estimated to feel impacts ranging from $0.8 million and $1.6 million in additional direct spending and between 12 and 23 new direct jobs in the Southeast region to between $4.4 million and $8.7 million in additional direct spending and between 49 to 97 new jobs in the Central region.

One convenient way to compare results across different regions or industries is the multiplier. The Type II multiplier is a simple ratio calculated by summing direct, indirect, and induced effects and then dividing that total by the direct effect. This can be done for Employment, Labor Income, Value Added, or Output measures. Multipliers capture the propensity of businesses and households to buy goods and services from within the region versus from outside sources (Table 10). Higher multipliers suggest that more local spending stays within a region. In essence, regions or sectors with higher multipliers will see larger economic effects from the same initial level of spending, as compared with regions or sectors with lower multipliers. The Northeast region has the lowest multipliers of the five regions, with an employment multiplier of 1.54 and an output multiplier of 1.56. The southeastern region has the largest multipliers, at 1.73 (employment) and 1.99 (output). It is interesting to note that this region has the smallest direct effects, but the largest multipliers, meaning there is less initial impact, but that the initial spending stays within the region. Conversely, the northeastern region has a larger direct effect (due to a larger logging industry) but more of the initial spending leaves the region, likely due to a smaller and less diverse economy.

Table 10 Regional multipliers for logging impacts

	Employment	Labor Income	Value Added	Output
State of Wisconsin	1.86	1.71	2.07	1.96
Central	1.74	1.47	1.77	1.73
Northeastern	1.54	1.39	1.65	1.56
Northwestern	1.60	1.40	1.68	1.62
Southeastern	1.73	2.00	2.37	1.99
Southwestern	1.72	1.47	1.77	1.68

DISCUSSION

Based on our harvest case study data, scoping assessment of most important constraints, we estimated that the most plausible scenario was a one-month increase in the logging season, which we further estimated to be between five and ten percent of the existing logging output. There appears to be a continuing shift from summer to winter, and lacking more concrete evidence, we use this one-month estimate. Our analysis of the economic impacts of forest management constraints is built on a scenario whereby the window of seasonal logging constraints is reduced by thirty days (one month) with a concurrent increase in the logging season. We selected one month because some of the most frequent and influential constraints we studied restrict harvest seasonality (as opposed to just adding costs to forestry operations) and typically reduce or expand the harvest season by about that amount of time. Using the data from our harvest case studies and insights from the forester and logger surveys, we estimated that increasing the operability by one month would increase overall production by about five to ten percent. According to the model, a five percent increase in production would directly add $7.5 million dollars in labor income and $16.1 million dollars in output. A ten percent increase in production would directly add $15 million dollars in labor income and $32.2 million dollars in total economic output.

We estimate that the direct impact on timber professionals of increasing the operable logging season by one month would be less than one percent of the $23 billion dollar direct output of the entire forest industry in Wisconsin (WIDNR 2012). Similarly, the $8.3 to $17 million dollar increase in direct value added resulting from one additional month of operability is less than one percent of the $6.4 billion dollar value added for the entire Wisconsin forest industry. As noted, this assessment does not include all the possible costs that such a change might create, as we did not directly model effects on landowners or primary wood users.

There are other, more difficult-to-quantify benefits to expanding the number of months during the year when loggers can operate. For example, study from Minnesota identified that expanding the logging season would make it easier for timber professionals to retain skilled labor year-round, invest in and realize a return on investment in new equipment, and repay loans (Blinn et al. 2015). Forest regulations can have significant economic impact, particularly as new regulations accumulate (Van Deusen et al. 2012). However, because of the complexity of the forestry economy, identifying how these economic impacts play out is difficult. For example, studies of restrictions put in place to protect the northern spotted owl in the Pacific Northwest imposed significant

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costs on wood consumers. Wood producers offset the costs of forest management constraints and reduced output with price increases, and so faced little economic impact (Murray and Wear 1998, Wear and Murray 2004).

Though it is difficult to measure the economic impact of timber harvesting constraints, it is even more difficult to measure the potential economic benefits of constraints. One example of the potential benefits of constraints that protect forest resources is oak wilt. Haight and colleagues (2011) estimated that in one Minnesota county, the spread of oak wilt in the county would have an $18 to $60 million dollar negative impact.

The oak resource in Wisconsin is one of the highest value wood resources in the state and loss of high-grade oak on better sites would result in a significant reduction in standing timber value and future value of forestland. Oak wilt constraints are known to be effective at slowing the spread of the disease to the unaffected counties in Wisconsin, and it is likely to have a tremendous economic benefit by postponing costs associated with infection and mortality. For example, an assessment of the federal program to slow the spread of the invasive gypsy moth (*Lymantria dispar*) estimated the benefits such as increased tree growth were worth between $21 to $33 million (Sills 2007).

Ecosystem services

BMPs, forest practices guidelines, recommendations, and regulations help protect the wide range of benefits Wisconsin's forests provide including forest productivity, wildlife habitat, clean water, carbon storage, recreation opportunities, and beautiful vistas that draw visitors from around the world. This wide range of benefits can be summed up in the phrase *ecosystem services* (Millennium Ecosystem Assessment 2003). These ecosystem services provided by nature include water regulation and purification, groundwater recharge, Mike Lynch

fish and wildlife production, soil creation, pollination, and mental and physical rejuvenation.

Defining and valuing ecosystem services is difficult because many ecosystem services have not been measured or quantified. However, valuing forest ecosystem services, particularly non-market services, can help ensure they are protected (Collins and Larry 2007). Balmford and colleagues (2002) argue that globally, conservation reserves have a 100:1 ratio of benefits to costs. Scarpa and colleagues (2000) found non-timber values were twice the timber values of trees. In the case of the northern spotted owl, a contingent valuation study suggests that harvest restrictions to protect the spotted owl produced economic benefits in excess of the costs (Haqen et al. 1992).

In Wisconsin, outdoor recreation generates as much as $11.9 billion in spending and supports 142,000 jobs (OIA 2013). Sport fishing generates a $2.3 billion impact on the state economy including $670 million (2011) in salaries and wages (Southwick Associates 2012). The 660,000 resident and non-resident hunters generate $1.8 billion (2001) in economic impact in the state, of which about 52 percent is related to deer hunting (IAFWA 2002). Wisconsin has the second-highest state rate of participation in birding, an industry that generates an impact of $106 billion (2011) nationally (Carver 2013). Recreation in Wisconsin's state parks generated $380 million in direct and another $120 million in indirect economic impacts (2013) (Prey et al. 2013). By one estimate, Wisconsin's wetlands provide over $3.3 billion (2011) in economic benefits each year (Earth Economics 2012). Two-thirds of the clean water supply in the U.S. comes from water that has been filtered through forested land, the majority of which is privately owned (Smail and Lewis 2009). The direct value of U.S. national forest headwaters is estimate to be over $27 billion per year (Smail and Lewis 2009).

The Conservation Reserve Program (CRP) could be used as an agricultural analogue for forest management constraints. The CRP encourages farmers to retire highly erodible and environmentally sensitive cropland and pasture from production and reduced soil erosion by 750 million tons per year (Ribaudo et al. 1989). In addition, the CRP program may be responsible for as much as $300 million dollars per year in increased outdoor recreational expenditures in rural areas (Sullivan et al. 2004). CPR has also contributed to the reversal of landscape fragmentation, maintenance of regional biodiversity, creation of wildlife habitat, and favorable changes in regional carbon flux (Dunn et al. 1993). A theoretical study of afforestation estimated over $130 million dollars annually in wildlife and soil benefits from converting 25 percent of Wisconsin's cropland to forest (Plantinga and Wu 2003).

Many of these ecosystem services (e.g. clean water, wildlife habitat, and recreation opportunities) are dependent on forests and affected by forest practices. Together with the value of forest productivity that is protected by many management best practices, they represent the "benefit" side of the cost-benefit relationship behind timber harvesting constraints (see the following section, *Assessment of Ecological Effects*). It was not within the scope of our study to compare the costs of harvesting constraints with the value of benefits they are intended to provide. Given the large differences in time scale, uncertainty of effects, and non-market valuation that would be involved, such a comparison would require a number of assumptions and would be difficult if not impossible to perform precisely. Despite the difficulty in measuring these values precisely, however, the importance of their benefits should not be understated, as any impacts to forest productivity and ecosystem services are of direct economic consequence to Wisconsin's economy and quality of life.

Summary

- Based on the harvest case study data, we estimated that expanding the logging season by one month would increase production by between five and ten percent.
- A five to ten percent increase in commercial logging activity directly adds between $16 million and $32 million to state economic output.
- The direct impact of increasing the logging season by 30 days would be less than one percent of the $23 billion dollar direct output of the entire forest industry in Wisconsin.
- The non-timber benefits forests provide through hunting, fishing, recreation, clean water, and other services are difficult to measure but potentially total in the billions of dollars.

ASSESSMENT OF ECOLOGICAL EFFECTS

BACKGROUND

Forest structure, composition, and productivity

Harvests, and hence forest management constraints, can change forest structure and composition (Webster and Lorimer 2002). The size of post-harvest forest openings helps determine post-harvest forest regeneration and composition, with smaller gaps favoring more shade tolerant species such as sugar maple in the Lake States (Bolton and D'Amato 2011). Age diversity is also a concern. Many northern forests are currently dominated by mature forests, while young and old growth forests are comparatively rare (Shifley et al. 2014). Most of Wisconsin's forests are dominated by stands over 40 years old, but only a tiny fraction of stands are over 150 years of age (Perry et al. 2012). For example, lack of age diversity in the forest can limit overall biodiversity by selecting for generalist species of wildlife and plants that do well in mature (not old growth) forests, while species requiring interior old growth forest become rare across the landscape. Additionally, species requiring fire regimes or other disturbances leading to early successional growth also become rare (Greenberg et al. 2011). Lack of disturbance, particularly surface fire, is partly responsible for the decline of some disturbance-dependent forest ecosystems, such as the Great Lakes coastal pine stands (Fahey 2014).

In years with shorter winter and reduced frozen ground or snow, Wisconsin timber harvests shift toward jack pine and red pine, which grow on soils less vulnerable to compaction and rutting, and away from aspen, black spruce, hemlock, red maple, and white spruce (Rittenhouse and Rissman 2015). A potential downside to forest management constraints that shift forest operations from the summer to the winter in some wet to mesic sites could be the reduction in mechanical soil scarification, which acts as a functional surrogate for natural surface fire by breaking up the duff layer build-up, allowing seeds to make contact with mineral soil. While forest operations that cause rutting and compaction have negative impacts on the forest, scarification of soil can help regeneration of some species. For example, in a Pennsylvania study, scarified areas had greater germination and survival of acorns than unscarified areas, which led to higher density of northern red oak (*Quercus rubra*) (Zaczek 2002). Similar results have been shown for white oak (*Quercus alba*) (Lhotka and Zaczek 2003) and white pine (Burgess and Wetzel 2000). Nevertheless, the winter harvest constraint is applied mainly to wet to mesic soils rather than the sandy soils that support many oak and pine stands. This limits the spatial effect of this constraint in forests with scarification/regeneration issues.

Invasive plants can reduce forest productivity, affect forest composition, and limit forest management options by affecting forest composition or by increasing management costs (Evans 2014). The presence of invasive species may constrain forest management and alter forest composition by inhibiting regeneration of desirable species. For example, managers may not implement a regeneration harvest because of concern about the presence of garlic mustard (*Alliaria petiolata*) known to inhibit regeneration of desirable hardwood species (Stinson et al. 2006). Other invasive plants that may force changes to forest management plans include common buckthorn (*Rhamnus cathartica*) and Tartarian honeysuckle (*Lonicera tatarica*). Both of these plants are well-distributed in Wisconsin and require additional time and expense for treatment in order to meet forest owner objectives (Czarapata 2005).

Constraints that limit the spread and impact of invasive plants are likely to mitigate changes caused by invasive species on tree and shrub species composition or regeneration. For example, since garlic mustard can inhibit regeneration (Meekens and McCarthy 1999), reducing the areas infested by this invasive plant may improve regeneration. Common buckthorn and Tartarian honeysuckle have been linked to reduced oak regeneration (Schulte et al. 2011). Common buckthorn invasion reduces plant diversity and may increase soil erosion (Larkin et al. 2014). A similar invasive species, glossy buckthorn (*Frangula alnus*) also negatively affects regeneration (Lee and Thompson 2012). Glossy buckthorn can take advantage of gaps opened by timber harvest and expand its population (Burnham and Lee 2010). As forests age, canopies close, and light levels at the shrub layer are reduced, glossy buckthorn is less competitive (Cunard and Lee 2009). Glossy buckthorn and other invasive species also may be better able to take advantage of changing climatic conditions than native species potentially increasing the threat posed by them (Dukes et al. 2009). Invasive species can work synergistically. For example, earthworms, which are not native to the Lake States, can facilitate the invasion of common buckthorn (Roth et al. 2015). In this case, reducing the spread of one invasive species can slow the advance of other invaders.

Finally, any discussion of the impact of harvests or forest management constraints on ecological attributes must be considered in the context of overarching environmental change. Wind storms and fire created disturbance regimes that allow for the persistence of shade-intolerant species (Schulte and Mladenoff 2005, Schulte et al. 2005). During the last 20 years, however, both the red oak and white oak species groups decreased in dominance in the Driftless Area of the Midwest (Knoot et al. 2015). Other factors such as the introduction of new species and diseases (Albani et al. 2010) or prolonged droughts (Booth et al. 2012) may change Wisconsin forests as well.

Carly Lapin, WIDNR
Wood turtle

Wildlife habitat

Impacts of forestry on wildlife populations, including rare and protected species, operate primarily through habitat alterations. Although there is potential for incidental take of bird nests during the breeding season, with resulting lower reproduction in that season (Hobson et al. 2013), as well as incidental fatality of wood turtles (Steen et al. 2006), most significant impacts result from direct and indirect habitat changes (Hunter 1990).

Adjustments to forest management practices can mitigate impacts and sometimes directly protect the species as a whole. Forest management constraints that target particular wildlife species (e.g., wood turtle and northern goshawk) typically target crucial components of habitat for a specific species. Other BMPs simply strive to maintain a forest with diverse composition and structure with the underlying supposition that to do so will optimize biodiversity of a managed forest (Hunter 1990). For example, the Wisconsin DNR recommends forestry practices that help to maintain sandy openings located within 1,000 feet of core aquatic habitat for wood turtle nesting. Riparian habitat for wood turtles may be more favored by selective harvest than clear-cutting since wood turtles appear to prefer low to moderate canopy cover at the microhabitat scale (Arvisais et al. 2002, Compton et al. 2002). These prescriptions, then, led to a constraint intended to protect wood turtle habitat by reducing harvests near streams during the turtle's most active season (March 15-October 31). Similar reasoning was used to protect nesting habitat of northern goshawk. In short, a habitat-centric approach is the main mechanism used for the protection and perpetuation of rare wildlife species.

Biodiversity

Biodiversity in general is usually considered at a minimum of three levels: genetic, species, and ecosystems (Hunter 1990). At a genetic level, foresters might seek to maintain the genetic diversity of particular tree species throughout a managed forest. Wildlife managers are often concerned with discrete genetic populations of species, usually of greatest concern when the species is rare on a larger landscape.

Thus, forest managers and wildlife managers are concerned with maintaining forests of varied species compositions (e.g., northern hardwoods, aspen-birch, oak-hickory, pine, lowland conifers, etc.) as well as forests of varied ages (e.g., old growth, mature, early successional, etc.). In addition, forestry practices concerned with maintaining biodiversity also seek practices that maintain forests in particular landscape positions. Thus, as mentioned above, practices to maintain structure of riparian forests and limit disturbance nest sites benefit wood turtle; practices that perpetuate blocks of mature to old growth forests benefit nesting goshawks.

The management constraints considered in this study address biodiversity in all these ways. The practices seeking to maintain oak and pine species will have direct repercussions on species using those forest types. Some species, such as Kirtland's warbler, are not only tied to pine forests but also to a particular age/structural condition (Cutright et al. 2006). Thus, appropriate habitat management for this species uses active forest management techniques that include logging and/or prescribed burning. Practices that seek to limit the spread of invasive species maintain biodiversity not only of the vegetative community by controlling invasive species that would otherwise dominate the system, but also by perpetuating habitat for the suite of organisms that use that particular forest type. In conclusion, forest management practices will have effects (both positive and negative) on particular wildlife species as well as habitat structure and diversity. Carefully designed sustainable forestry practices can be used to optimize forest management effects on biodiversity.

Water quality

The potential ecological impacts of forestry operations on water quality are well known, but can be minimized with implementation of BMPs (Aust and Blinn 2004, Wilkerson et al. 2010, Cristan et al. 2016). The Wisconsin DNR Department of Forestry describes non-regulatory water quality BMPs that foresters and land managers employ during forestry operations (WIDNR 2011).

METHODS

The ecological effects of forest management constraints were evaluated in four categories: forest structure, composition and productivity; wildlife habitat; biodiversity; and water quality (in the results section, wildlife habitat and biodiversity are discussed in combination). Forest structure and water quality were evaluated through a literature review, while wildlife habitat and biodiversity were evaluated using predicted responses of species which served to indicate the general effect of the constraint—positive, negative or neutral. For wildlife habitat and biodiversity, the general effect across the indicator species was summarized. In general, there is limited research on the efficacy of many of the constraints we considered, with the notable exception of water quality BMPs (e.g., Cristan et al. 2016). Even where some research exists on the efficacy of particular management practices, unless the specific constraint in Wisconsin has been assessed, the applicability is limited.

For example, treatments for garlic mustard have been studied (Shartell et al. 2012), but not the effectiveness of Wisconsin's best management practices for invasive species. Similarly, research has assessed the effectiveness of annosum treatments at the stand level (Cleary et al. 2013), but not ability of these treatments to reduce the impact of annosum at the landscape level in the US (but see Vollbrecht and Jørgensen 1995). Field-based research into the effectiveness of forest management constraints in achieving their desired aims would help fill this gap.

Forest structure, composition, and productivity

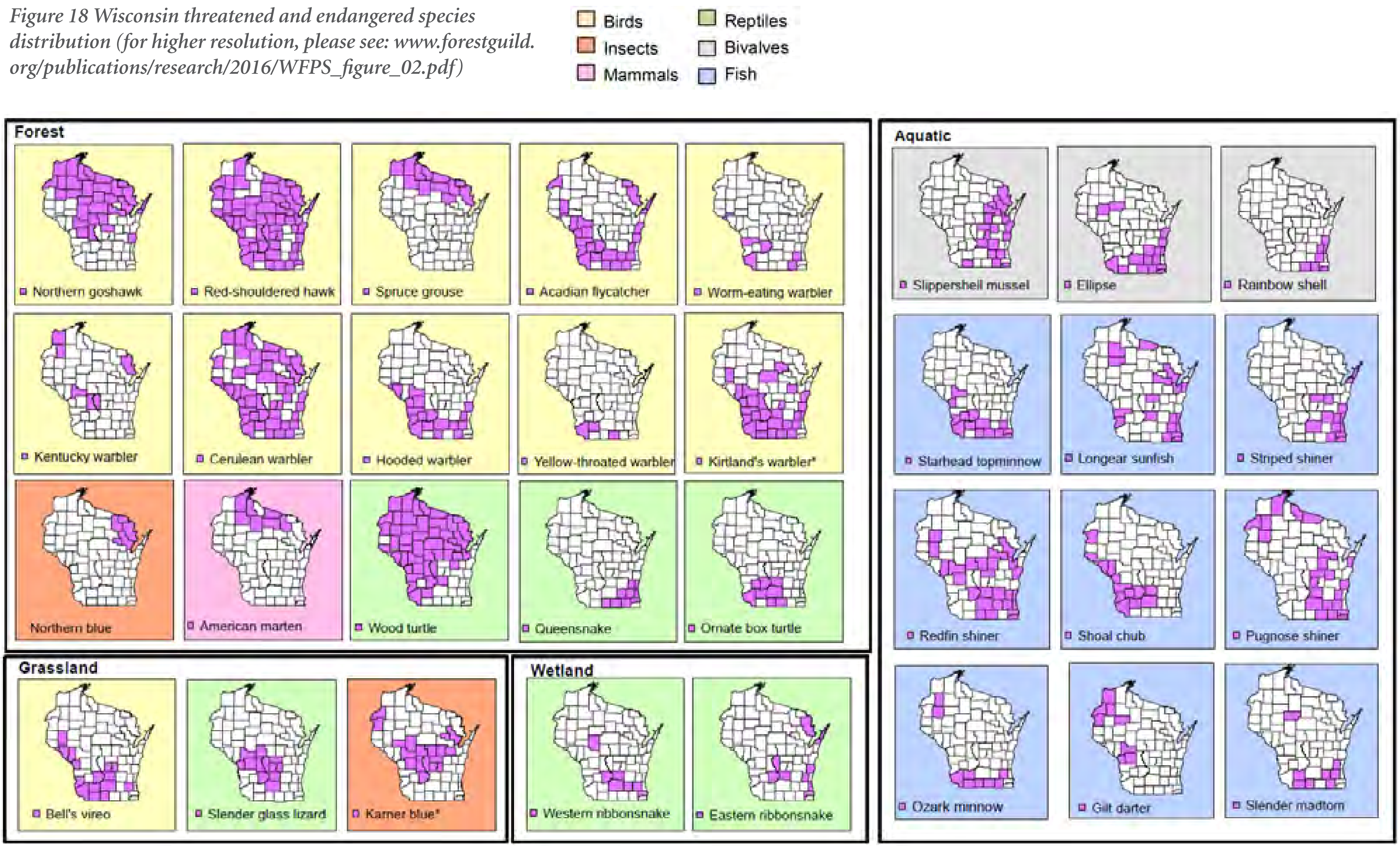
A literature review was used to assess the effects of harvest constraints on forest structure, composition, and productivity. Ecological forest health is an area of active research, with relatively new work focusing on the effect of soil community health on forest productivity, and other work examining the long-term effects of invasive species. In general, harvest BMPs and constraints are aimed at perpetuating healthy and economically harvestable forest stands. Thus, it is no surprise that these five management constraints evaluated herein might be anticipated to have positive impacts on forest structure, composition, and productivity.

Wildlife habitat

The effects of constraints on wildlife habitat were evaluated by selecting representative "Species of Greatest Conservation Need" (SGCN) known to use forest ecosystems subject to commercial forestry practices (WIDNR 2016d). Five forest types representing the majority of Wisconsin's harvestable cover types were considered: northern hardwoods and maple basswood forest (HW); oak and oak-hickory forest (OH); red, white and jack pine forest (P); aspen and aspen-birch forest (AB); and lowland forest (LF, both deciduous and conifers). The Wisconsin DNR's rare species website was used to identify the significant native community or habitat association for each SGCN species (WIDNR 2016c). These habitats were cross-walked with the five forest types. This process ensured that the habitat associations of final wildlife list of 14 species (10 birds and four mammals) encompassed the five forest types. Additionally, although associated with one or two forest types, the 14 species selected used a range of successional stages, from early successional conditions to mature forest conditions. Species that are listed as threatened or endangered are discussed in the Biodiversity section.

Each constraint was evaluated for its short-term and long-term effect on a species. Short-term effects were defined as those that directly affected individuals, such as direct mortality or a disturbance that caused loss of reproductive productivity in the year it occurred. Short-term effects, by definition, did not consider impacts on populations over time. Long-term effects were defined as those that caused temporal changes in habitat types or quality and thus had indirect effects on populations of a species over longer periods. These changes may have implications for the long-term persistence of a species, although population-level analysis of the long-term effects was outside the scope of this study. The effect of a harvest constraint was evaluated as positive, negative, or neutral for the wildlife habitat, as represented by a forest type.

Figure 18 Wisconsin threatened and endangered species distribution (for higher resolution, please see: www.forestguild.org/publications/research/2016/WFPS_figure_02.pdf)



Biodiversity

Thirty-two forest-associated threatened and endangered (T&E) species were used as indicators of the effects of the forest management constraints on biodiversity. The species included in the list require forests for all or a portion of their life cycle. If the distribution of a T&E species did not overlap with the geographic extent of a forest harvest constraint, that constraint was not evaluated for that species. The county-level distribution for each species was obtained from Wisconsin's Natural Heritage Inventory (Figure 18). Although the special concern species, Northern goshawk, is associated with a forest harvest constraint, it is included in the list of rare species because it is considered an indicator of extensive, mature forest conditions on the landscape.

Species were grouped by broad habitat types: forest; open woodlands and savannas; aquatic systems occurring in forested landscapes; and wetlands occurring in forested landscapes. The species selected represented birds, mammals, insects, reptiles, bivalves, and fish. Grassland species were included if they also occurred in open woodlands and savannas of oak and pine barrens that may be subject to logging. Aquatic species selected occur in small streams and rivers of forested landscapes and thus are potentially subject to impacts.

As with wildlife above, each constraint was evaluated for its short-term and long-term effect on each species. Under these short-term and long-term categories, a harvest constraint was evaluated for each species as positive, negative or neutral. If a constraint acted to favor or protect a species, it was considered positive. For example, a buffer and seasonal constraint to protect a northern goshawk nest site likely would have a positive effect on other forest-nesting T&E birds if they also nested in the buffer zone. By contrast, it would not favor any forest-dwelling species requiring early successional conditions. Where this was the case, the constraint was evaluated as having a negative effect. A neutral effect indicates the constraint does not help or harm a species. For example, annosum root rot treatments in pine barrens may preserve pines but not all species that may occur in pine barrens specifically require pines in their habitat. A negative effect is defined as causing direct mortality of adults, young, and eggs, or one that leads to mortality of young and eggs when an adult abandons a territory as a result of a disturbance. For example, removal of common buckthorn during the June to early July nesting season of long-distance migratory bird species would likely have a negative effect on individuals that nest in forests with a shrub understory, causing direct destruction of nests or nest abandonment and the eventual death of young. For all constraints, vehicle and foot traffic during treatment is considered a minor disturbance having little effect on biodiversity, as long as best practices are followed. It was assumed that best forest practices would always be followed, which would render neutral some practices that have potentially negative effects when best practices are not followed.

Fred Clark (top)
Zander Evans (lower)

Water quality

A literature review was performed to assess the effects of forest management constraints on water quality. The effect of forestry on water quality is a well-understood, well-researched field, with comprehensive state and federal agency guidance available to foresters and land managers. An excellent recent review of water quality BMPs demonstrates the effectiveness of these techniques in forestry (Cristan et al. 2016). In general, implementing harvest BMPs to protect water quality is a standard operating procedure in many forestry operations, and was considered when reviewing the effects of some constraints.

RESULTS

Effects of constraints on forest composition, structure and productivity

Forest health components—forest composition, structure and productivity—result from a rich interplay of factors (Grier et al. 1989), many of which are affected by the five management constraints under consideration. For example, it is well known that forest health is inextricably bound to soil health; soil health is the foundational factor underlying forest composition, structure and productivity. As a consequence, constraints that minimize negative impacts to soils also limit negative impacts to forest composition, structure and productivity (Stone 2002). Other constraints are more targeted in their effects. To illustrate, control of species-specific diseases can perpetuate specific forest components (such as pine or oak) and thus perpetuate a forest that is diverse in composition and structure. Practices that control invasive species likewise can affect both structure and composition and even productivity of the affected stand (Corns 1988). In this section we discuss some of the more obvious effects of the five prescribed management constraints on forest composition, structure and productivity. Many of these effects on forest health will be alluded to again under the following section on effects of constraints on wildlife habitat and threatened and endangered species since impacts on species are most often the result of changes in their habitat.

Winter harvest

Winter harvest is usually prescribed for forest harvest occurring on fine to medium textured soils that are typically poorly drained to very poorly drained. This constraint, limiting harvest when the ground is frozen, is intended to protect the physical properties of soils by minimizing compaction, rutting, and puddling (Lantagne et al. 1998, Fisher and Binkley 2000). The prevention of these impacts is intended to protect soil structure, texture, porosity, density, drainage and hydrology. If effective, these constraints help foster a biologically diverse and resilient soil community which optimizes tree growth and perpetuates a diversity of species. By minimizing soil disturbance and compaction of the top soil layers, winter harvest limits leaching of nutrients such as phosphorus, retaining nutrients and making them available for tree growth (Arocena 2000; WIDNR 2011). By minimizing soil compaction (especially in wet and mesic soils) winter harvest can help avoid root damage to trees. In aspen stands, for instance, damage from soil compaction has been demonstrated to reduce regeneration resulting from suckering (Shepperd 1993). Minimizing soil compaction also promotes tree growth by preserving soil macropores,which promotes aeration and drainage in the rooting zone (Williamson and Neilsen 2000).

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Oak wilt

Caused by the fungus, *Ceratocystis fagacearum*, oak wilt can spread overland via beetles as vectors in spring and early summer causing highly variable damage (Menges and Loucks 1984). A review of oak wilt management found treatment could be effective, particularly when combined with educational efforts (Koch et al. 2010). The harvest constraint from April to July is formulated to minimize this spread. If this constraint is assumed effective in slowing

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the spread of the disease and retaining mature oaks in the forest canopy, the effect is positive in that it helps maintain a more diverse forest composition at stand and landscape levels than if oak were diminished or absent, and also helps perpetuate commercially valuable oak species.

Annosum

Annosum is mainly a concern in pine stands and plantations, typically on well drained, sandy soils. The fungicide prescriptions for annosum control are highly targeted (granular or backpack spray) on cut stumps as a preventative against infection (WIDNR 2016a), likely limiting widespread impacts on the soil community. If the constraint is assumed effective in preventing the spread of annosum, then a positive effect is anticipated because pine will be retained as part of the structure and composition of a stand and landscape. There may be potential for a broad spectrum fungicide treatment to deplete desirable mycorrhizal fungi in the soil around the stump which could, in turn, have a negative long-term effect on productivity. Along these lines, concerns have been raised about effects on other plant species and soil fauna resulting from chemical treatments, including accumulation of boron on other plant species (Gupta et al. 2014) and changes in the soil faunal community (Varese et al. 2003). Both of these could potentially affect forestry productivity over the long term. In response to these concerns, in Europe, there is movement away from chemical solutions and towards biological agents (Varese et al. 2003).

Invasives control

In multiple ways, invasive species affect forest composition, structure, productivity, and even patterns of carbon sequestration (Moser et al. 2009, Evans 2014). Through direct competition, invasive species can usurp native plant niches, resulting in reduced forest vegetative diversity and simplification of structure and composition. There is also evidence that invasive species have long-term effects on ecosystem processes as well as soil nutrient cycling across a variety of ecosystem types (Gordon 1998, Mascaro and Schnitzer 2007, Ehrenfeld 2010). Given the negative effects of invasive species reported on forest ecosystem processes, structure, and composition in these and other studies, control measures that reduce dominance by invasive species after harvest will likely have positive impacts on all attributes of forest composition, structure and productivity.

Wildlife buffers

Wildlife buffers, particularly riparian buffers, serve a wide variety of functions including providing connective corridors on the landscape, protecting water quality, and providing habitats for a diversity of wildlife that can often include rare species, such as wood turtle of this study (NRC 2002; Semlitsch and Bodie 2003). Wildlife buffers lying within a forest stand create a node of structural and compositional diversity. Both may harbor bird and mammal species that aid in the control of pests that could affect productivity, and provide seed sources for adjacent stands, which contributes to structural and compositional diversity (Hunter 1990). The anticipated effects on goshawk and wood turtle as indicators of wildlife effects are found in the section *Effects of constraints on wildlife habitat and biodiversity*.

Summary

In general, the prescribed constraints are expected to have positive repercussions on forest composition, structure and productivity operating both directly in the short term and indirectly over the long term. This should come as no surprise since most of these prescriptions are simply extensions of existing BMPs that have been in place for some time to protect water quality, soils, tree health, and rare species of fauna and flora.

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Effects of constraints on wildlife habitat and biodiversity

The effects of constraints on wildlife habitat and its associated biodiversity are generally similar to effects on threatened and endangered species (T&E) and are, in turn, closely tied to effects on forest composition, structure and productivity. This section provides additional explanation and annotation for the tables in Appendix II. Effects are considered for T&E species on a habitat basis. If a species rarely or never uses a habitat with a constraint, effects were not considered for that particular combination of species and constraint. Categories of short-term and long-term effects and rankings of positive, neutral and negative effects are discussed in the Methods section.

Winter harvest

As mentioned, winter harvest is a constraint for forest stands with soil types vulnerable to rutting and compaction. This includes many hardwood and aspen stand as well as lowland hardwoods and softwoods. It usually excludes forest stands on sandy soils, such as pine stands and many oak stands.

The short-term, direct effects of winter harvest affect only a limited number of bird species. This is because most avian species in Wisconsin migrate farther south in the winter. This attribute of Wisconsin avifauna limits destruction or disruption of nesting attempts by most species during any particular winter harvest. A possible exception is red crossbill which can breed in the winter during a good cone crop year and might find breeding habitat in a mixed conifer/aspen, hardwood/conifer, or lowland conifer stands (Adkisson 1996, Cutright et al. 2006). Spruce grouse might also experience winter habitat disturbance in lowland conifers that could affect short-term survivability, at least of that year's young.

Under this constraint, mammal species using any particular forest stand during winter harvest may experience some short-term disturbance, but not usually during their breeding season. Larger mammals typically have home ranges that extend over areas larger than a harvestable forest stand, thus mitigating the effects of any one particular harvest. The most likely impacts of winter harvest are habitat disturbances for small mammals with limited range sizes, such as woodland vole or northern flying squirrel (Long 2008).

The long-term effect of winter harvest on wildlife habitat is a more nuanced issue. The immediate change in forest structure and composition from a winter harvest is not likely to be significantly different from a warm season harvest. Regardless of the season, changes in forest structure, especially of trees and midstory saplings, in response to the cutting regime, will favor certain species over others (Hunter 1990). For example, a selective winter or warm season harvest that reduces canopy closure will likely result in an enhanced midstory of saplings. In northern Wisconsin, a northern hardwood forest with scattered mature trees and an enhanced midstory layer is often attractive to nesting black-throated blue warblers (Cutright et al. 2006).

Positive effects of winter harvest are more likely to be realized through positive effects on the soil and ground cover community. In stands with soils vulnerable to compaction and rutting from warm season operations, winter harvest favors a healthier and more diverse soil and ground cover community through minimization of ground impacts and introductions of invasive species. This, in turn, is predicted to create favorable foraging and nesting conditions for a variety of bird species nesting in shrubs from the ground to about 5 feet up by providing suitable nest sites and camouflage from predators. This is particularly important in small fragments of forest (Wilcove 1985). A similar positive habitat effect can be expected for mammal species that use ground level habitat (woodland vole, woodland jumping mouse, northern flying squirrel). In addition, a healthier soil community and reduced compaction and root damage may translate to more robust growth of tree species, favoring wildlife that use the taller forest strata as well. In general, this constraint will likely maintain or improve forest vegetative diversity and growth at all successional stages. This, in turn, creates more options in choices of habitats through time and accommodates a wider variety of species (Cody 1985, Holmes and Sherry 2001, NWF 1994).

Oak wilt

The oak wilt constraint avoids harvest from April to July to slow the spread of this oak disease. This harvest avoidance window greatly limits short-term, direct effects on most avian species in Wisconsin as harvest avoidance timing corresponds to their peak breeding season. It likewise limits short-term effects on most mammal species.

If this avoidance indeed helps perpetuate an oak forest, or an oak component in a mixed species forest, then the effects are almost universally positive. Oaks of all species are valuable mast crop species and also provide many nesting niches for a diversity wildlife at all stages of an individual tree's life. Oak forests have long been widely recognized for their value to a wide variety of wildlife (McShea et al. 2007). Oaks also provide a valuable component to soil litter with their slower decomposing leaves (Baker et al. 2001, Piatek et al. 2010). Controlling oak wilt, however, could limit patches of early successional vegetation (Tryon et al. 1983) and thus limit the occurrence of wildlife species requiring that disturbance-driven habitat.

Annosum

The fungicide (Disodium Octaborate Tetrahydrate or Sodium Tetraborate Decahydrate) application to limit incidence of annosum root rot targets stumps after harvest using a granular or spray formulation. Although the harvest itself likely will have both positive and negative effects on the wildlife community composition, there is unlikely to be much direct impact from fungicide application on species inhabiting pine forests or plantations. There is no evidence of immediate toxicity of the boron component to wildlife given the targeted application to stumps.

There is limited potential for aquatic pollution due to the upland nature of most pine harvests on sandy, well drained soils and the utilization of BMPs by watercourses. There are limited data on persistence and bioaccumulation effects in the environment, both of which are tied to the frequency and amount of application in a specific location. The long-term effects on the ecosystem—to perpetuate pine forests and a pine component in mixed forests—is predicted to be positive on a number of species (e.g., red and white-winged crossbills, pine warbler, spruce grouse, northern flying squirrel, etc.) that need a pine forest habitat.

Invasives control

Invasive plant species control (removal of woody invasives such as buckthorn and honeysuckle) prior to harvest has the potential to disturb nesting and breeding of forest species of birds and mammals that use the shrub or ground layer. Nevertheless, long-term effects are likely to be positive, particularly if native species are able to re-establish after invasive removal. Native plants have many more interconnections with the food web than the introduced shrubs such as buckthorn targeted by this constraint (Knight et al. 2007).

Research has shown the apparent negative effects of invasive shrub as nesting habitat for songbirds. American robins nesting in common buckthorn and honeysuckle experienced a higher predation rate than those nesting in native shrubs (Schmidt and Whelan 1999). Artificial nest experiments have also demonstrated a negative effect of non-native shrubs (Borgmann and Rodewald 2004). Other studies, however, have not borne this finding out (Meyer et al. 2015). This could be due to various and interacting factors including variability among nesting species, differences in the extent of exotic invasion, as well as differences in the larger ecological matrix. Invasive shrubs can also alter long-term forest structure through adverse competition (Hutchinson and Vankat 1997) which, in turn, is likely to affect the faunal community.

Wildlife buffers

Wildlife buffer constraints include both harvest width and seasonal constraints. Wildlife buffers are used to protect the nest site, nesting habitat, and other essential habitats of species which return each year to the same site over several years. Buffers along known wood turtle streams are intended to extend about 300 meters from the stream where turtles are known to occur. Harvest within this buffer is to be avoided from March to September, the wood turtle's active season. Buffers around known northern goshawk nests encompass a mile around the nest, with harvest scheduled from August to January. The seasonal harvest limits in buffers of wood turtles and goshawks thus both greatly limit short-term direct effects of harvest not only on their target species, but also on migratory and resident birds and mammals whose reproduction predominately occurs from April to July.

Mike Lynch

Goshawk is used as an indicator of wildlife response, as already discussed. There is some disagreement, however, about the long-term efficacy of goshawk nest site reproduction over the long-term. In an Arizona study, despite nest site protection occupancy of nest sites dropped by 75-80 percent and nestling production was 95 percent lower over multiple years (Crocker-Bedford 1990). This study concluded that landscape-scale factors operating beyond the protected nest site habitat were more important in maintaining goshawk populations long term than were nest site buffers. Goshawks may need several patches of suitable nesting habitat in a single territory. A summary by Minnesota scientists also concluded that over the long term, successful goshawk management likely requires a landscape approach (Audubon Minnesota 2014). The Arizona study, however, considered effects in a landscape that differed considerably from Wisconsin's north woods and therefore different management approaches may be necessary. We do not know of a study that examined as rigorously as the Arizona study the long-term effect of buffers on goshawk nesting success in Wisconsin.

On the other hand, long-term effects of buffer constraints are likely to be positive or at least neutral for biodiversity overall, as indicated by the overall response of T&E species and SGCN wildlife indicator species. This is because buffers introduce pockets of structural and species diversity at a landscape level (Hunter 1990). For species which depend on mature forest patches and have territory sizes smaller than these wildlife buffers—such as cerulean warbler, wood thrush, and veery—a positive effect is anticipated since their preferred habitat is maintained. Thus at the stand level, buffers are positive for species that prefer mature forest or undisturbed sites. For species preferring early successional habitat, however, the effect at the stand level of not harvesting would be negative in the short term. Early successional species are, however, generally favored at a landscape level in Wisconsin, as suggested by white-tailed deer densities and other indicators of early successional conditions.

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Effects of constraints on water quality

Erosion-prone sites are those that are subject to water runoff and soil loss when disturbed. Forest soils on 15 to 35 percent slopes have a moderate erosion capability, while soils on greater than 35 percent slope have a severe erosion capability (WIDNR 2011). Soils that have sands, silts, or organic soils as their main constituents, and, depending on stream width, are within 35 to

100 feet of water are vulnerable to disturbance during harvest which could contaminate adjacent wetlands, streams, and lakes with sediment (WIDNR 2011). Forestry best management practices (BMPs) are implemented at high rates, 89 percent in one national study (Ice et al. 2010). Moreover, they are very effective in dealing with water quality issues associated with forestry practices (Cristan et al. 2016).

Winter harvest

Winter-only harvest in forests with vulnerable soils will have a positive effect on water quality. With frozen ground, soils are stabilized and much less subject to rutting or erosion that may cause sedimentation in nearby wetlands and waterways (Ehnes 1998, Berger et al. 2004, Reeves et al. 2012).

Oak wilt

Oak wilt treatment amounts to no harvesting in oak forests from April to mid-July. This harvest constraint in oak forests located on level, well-drained sandy soils, such as oak woodlands and savannas, should have little to no effect on water quality because these soils are less vulnerable to rutting, compaction, and erosion than finer-textured soils (Reeves et al. 2012). The WIDNR (2011) and Reeves and colleagues (2012), however, consider sandy soils on slopes as having high erosion risk; therefore, oak forests on sloping sandy soils are vulnerable to erosion, regardless of time of year. Nevertheless, expected implementation of BMPs will minimize impacts to water quality.

Northern hardwood forests dominated by red or white oak, or mixed stands with sugar maple and basswood, may have finer-textured soils that are subject to rutting, compaction, and erosion. Where slopes near open water are involved, the risk of sediment transport with runoff into water resources increases (Ehnes 1998, WIDNR 2011). A no-harvest constraint from April to mid-July protects these soils for much of the growing season, including the spring melt when soils in swales and gullies may be saturated, but implementing BMPs properly also minimizes the risk of impacts to water quality.

Annosum

Assuming that water quality BMPs are followed and chemicals are applied as directed, annosum treatment is unlikely to have physical and chemical impacts on water quality. Unless there is a spill or improper application of the treatment near water, there should be no effect on water quality.

Invasives control

Control of invasive plants can have no effect on water quality if BMPs are followed. Mechanical cutting of honeysuckle, garlic mustard, and common and glossy buckthorn during initial treatment may disturb soils that could erode into wetlands and waterways. Glossy buckthorn, the less common of the two species, is more closely associated with aquatic habitats than common buckthorn (USDA 2016). No or minimal effect is anticipated, however, if heavy equipment is not used within 15 feet of a wetland or water body during the growing season, and within 15-50 feet of these features when ground is frozen or soils are dry (WIDNR 2011). No chemical effects on water quality are anticipated in the second year during follow-up treatment if the herbicide used is applied properly and rated for use in wetlands and other aquatic systems, such as the Glyphosate chemical under the brand name Rodeo (Rodeo is non-toxic to aquatic organisms, but is highly toxic to aquatic plants). Washing heavy equipment to remove invasive seeds can also generate loose soils that may wash into nearby aquatic habitats. This impact can be avoided if equipment cleaning occurs in a containment area (Fleming 2005). In general, no negative impacts on water quality are anticipated if BMPs are followed.

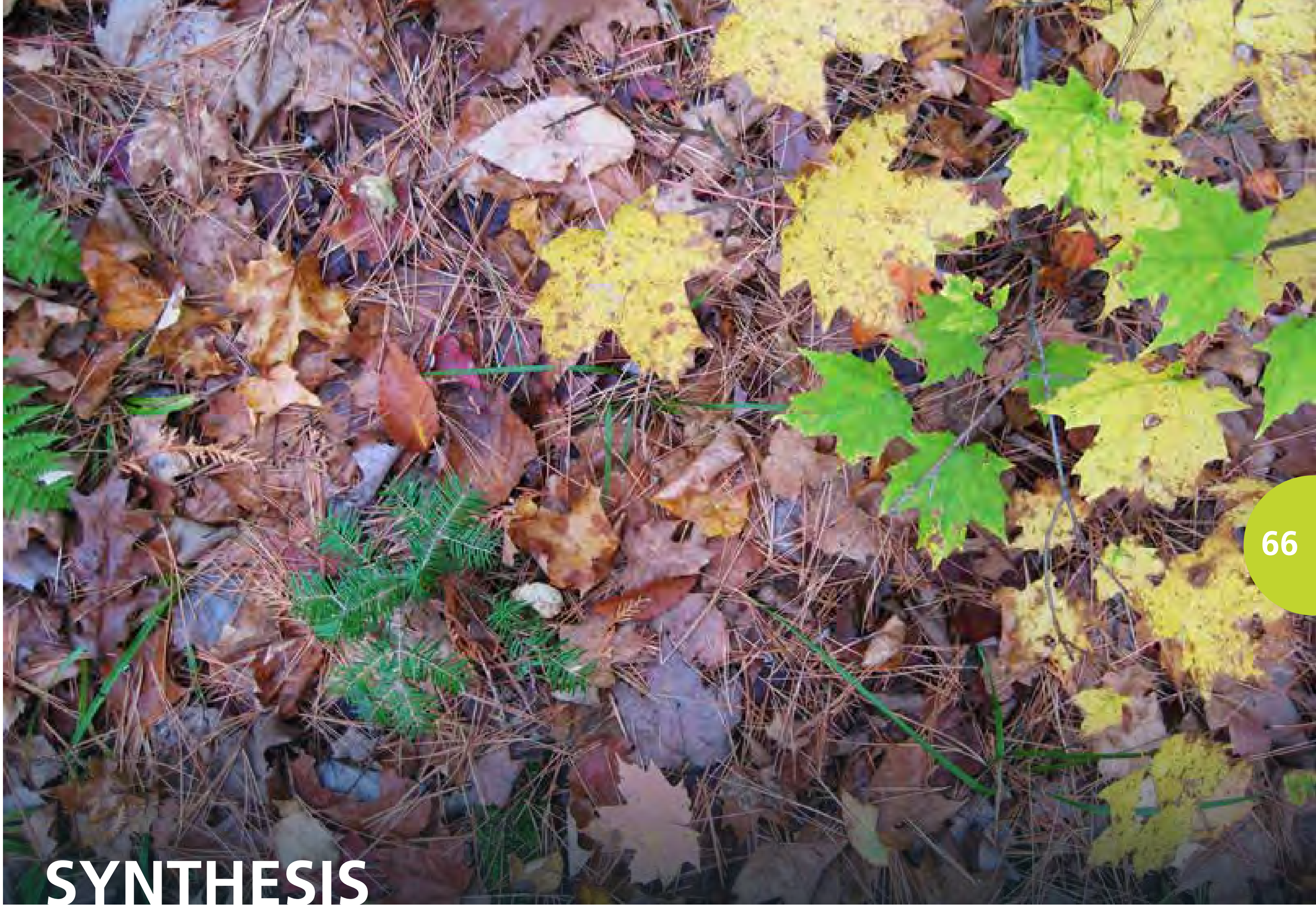
Wildlife buffers

Breeding season buffers for northern goshawk and wood turtle are anticipated to have neutral or positive effects on water quality in wetlands and water bodies where they occur in or upstream of a wildlife buffer. Since logging will not occur inside wildlife buffers during the proscribed period, soils are protected, avoiding sedimentation into waterways in the breeding period of these two species. Nevertheless, existing BMPs are designed to protect water quality even without wildlife buffers, and are implemented successfully in most cases (Cristan et al. 2016).

While we assumed forest management constraints were reasonably effective, further research examining the achievement of stated desired outcomes from implementation of constraints is warranted. For example, northern goshawk buffers may protect a nest site in the short term, but over multiple years landscape conditions may be more influential on persistence of nest sites. In another example, water quality BMPs appear to be widely applied and very effective, and perhaps are duplicative of winter harvest restrictions intended to protect water quality. On the other hand, winter harvest restrictions appear to have long term positive effects on forest structure, composition and productivity.

Summary

- There is limited research on the efficacy of the forest management constraints, with the notable exception of water quality BMPs. Future research on the specific constraints in Wisconsin could fill this gap.
- In general, the forest management constraints regarding harvest and treatments for tree diseases are expected to have positive repercussions on forest composition, structure and productivity particularly over the long term. For example, winter harvesting constraints promote forest health by protecting soil structure, integrity, and health, and also promote understory and ground cover diversity. These variables often are correlated with enhanced tree regeneration. A diverse, healthy forest, in turn, provides habitat for a greater variety of wildlife than a forest in poor condition.
- If oak wilt or annnosum constraints indeed help perpetuate an oak or pine forest, or an oak or pine component in a mixed species forest, then the effects are positive for species needing those habitats or dependent on oak or pine at some point in their life cycle.
- Constraints that reduce harvesting in spring and early summer generally benefit a wide range of wildlife and protected species in the short term by avoiding direct impacts to habitat during the predominantly May through July breeding season.
- Constraints such as winter harvest and riparian buffer zones, which are implemented to prevent sediment inputs into nearby water bodies, have a positive effect on water quality but the effect may be equal to those achieved with individually implemented BMPs.



Caption Needed

SYNTHESIS

This study examined the scope of selected forest management constraints in Wisconsin, the potential for the constraints to shift forest harvesting from summer to winter months, and the predicted economic and ecological consequences of forest management constraints. The following *Synthesis* section is based on more detailed results and discussions in the preceding sections.

SCOPE OF FOREST MANAGEMENT CONSTRAINTS

Numerous constraints designed to protect or enhance forest productivity, safeguard rare species, control invasive plants, or reduce the impact of forest pests affect forest management in Wisconsin. These constraints take many forms including regulations that carry the force of law, requirements tied to participation in programs with incentives, or voluntary guidelines. Foresters and timber professionals use professional judgement to apply constraints for all of these reasons in a variety of contexts. In addition, many forest owners apply management constraints to avoid real or perceived conflicts with other land uses (especially recreational activities) or to provide what owners may view as extra protection against undesirable outcomes. Finally, other constraints also affect forestry such as road weight limits or access limitations arising from land parcelization.

In our surveys, foresters and timber professionals reported that among all constraints addressed in this study, they most frequently applied constraints designed to protect water quality and forest productivity. Both of these re-

Fred Clark (left), Mike Lynch (right)

source values carry a high level of economic and environmental importance. Other constraints such as requirements to harvest aspen stands in the winter, employ annosum root rot mitigation measures, or follow biomass harvesting guidelines were applied much less frequently. The timber sale descriptions we studied were not consistently specific about the reasons why a seasonal constraint was applied and rarely identified areas of overlap between multiple constraints. In our review of 170 timber sale records, forest management constraints of some kind were applied in approximately 95 percent of cases, with only eight sales (five percent) allowing logging for a full 12 months of the year.

Most foresters and timber professionals value and are supportive of forest management constraints that protect forest resources. In our survey, over 70 percent of timber professionals indicated they believed protecting forest resources and values was either extremely or moderately important. Water quality and forest health received the highest importance with 85 percent of respondents indicating these values were at least moderately important to protect. In most cases, foresters and timber professionals reported on our survey that they apply constraints based primarily on professional judgment. In conversations, several practitioners noted that they would adhere to most constraints regardless of whether they were required to do so by law or policy because they are ethically obliged to apply the best science to their work and to act to protect the long-term health of the forest.

It is also important to highlight that other constraints that we did not assess may have even greater impacts on forestry operations without the benefit of protecting social, environmental, or economic benefits. For example, one study concluded that the size of forest holdings, distance to roads, population density, and owner attitudes toward harvest reduce wood availability by about 52 percent in Wisconsin (Butler et al. 2010). Forester responses to our survey support that conclusion, indicating that proximity to mills, species, quality, volume, competition between loggers, and the health of the United States economy all affect stumpage prices more than seasonal timber harvesting restrictions and government regulations. Other recent research highlights the significance of low timber prices and large equipment investments in limiting loggers' ability to adapt to changing conditions (Geisler et al. *In press*). A 2010 survey of timber professionals identified fuel prices, mill prices, stumpage prices, and equipment maintenance as the top four factors that affect logging business profitability (Rickenbach et al. 2015).

POTENTIAL SEASONAL SHIFT

Collectively, the constraints from state policies, federal regulations, professional judgement, environmental and weather conditions, and the preferences of forest landowners reduced the average harvest sale operation window to 6.5 months per year, although the particular months of allowable operation varied greatly by sale. While 35 percent of the timber sales we studied limited operations to frozen ground conditions, another ten percent did not allow winter harvests. A separate study of 143 timber sales in Wisconsin found 69 percent of sales had seasonal restrictions (Herrick 2015).

The summer months have the most accumulated constraints. Overall, forest management constraints have a larger impact in the southern counties due to the higher prevalence of oak wilt, annosum root rot, invasive species, and the generally shorter winter logging seasons. Our examination of constraints highlights that changes to an individual constraint may not necessarily increase productivity because another constraint may still apply. For example, if oak wilt constraints were no longer to limit logging in July, areas released from that constraint could still encounter restrictions as a result of BMPs for water quality or frozen ground requirements.

Policies that seek to minimize costs of forest management constraints while also avoiding unintended negative consequences deserve careful consideration. This is particularly important because of the potential for existing constraints to expand in scope or for new issues to create significant additional disruptions for forest management. For example, given the documented reduction in the winter logging season of up to three weeks over the last 60 years (Rittenhouse and Rissman 2015), the changing climate may continue to shorten the winter logging seasons even if the degree and variability of that change is impossible to predict. Anecdotally, timber professionals at our listening sessions reported observing an earlier spring breakup over the past several years, which has resulted in the loss of as much as two weeks of operation. If predictions for shorter winter seasons continue to play out, fewer days of operation and higher road access expenses could significantly increase the costs of forest management.

ECONOMIC CONSEQUENCES

The costs of forest management constraints are not evenly distributed across organizations, actors, or geography. During our listening sessions and in the survey results, timber professionals made it clear that seasonal constraints created a significant economic burden on their operations. The majority of forester survey respondents, however, indicated constraints either had no direct impact or only a small negative impact on their organization.

The harvesting constraints with the most significant costs and impacts are generally those designed to protect forest productivity. Many of these constraints have been developed through stakeholder-based processes that included forest industry representatives, which suggests that these guidelines are viewed as protecting economic advantages for forestry among other benefits. For example, oak wilt or annosum root rot constraints help protect valuable timber resources; invasive species BMPs slow the spread of damaging plants that affect forest regeneration; and frozen ground constraints guard against impacts for forest soils that will reduce growth and productivity. However, detailed field research might identify areas where it is possible to reduce constraints while still achieving the needed protections.

Based on our harvest case study data and scoping assessment of the most important constraints, we estimated that the most plausible scenario to model was a one-month increase in the logging season. This scenario reflects our estimation of the effect of reduced oak wilt or frozen ground constraints. After gathering both quantitative and qualitative information about the specific effects of forest management restrictions, we used an economic modeling tool to estimate the impact on Wisconsin's commercial logging sector. We modeled a scenario that compared current conditions to the inclusion of 30 days of additional harvest availability. We predicted that the addition of one month to the logging season equates to a five to ten percent increase in overall production in the commercial logging sector.

Other modeling scenarios would likely generate significantly different results. We did not model an impact of increased production on landowners because for large landowners, timber sales typically generate investment income that is not spent locally, and over 80 percent of small landowners derive no annual income from their forestland. Another element not included in our economic impact assessment was the forest product sector, i.e., pulp and paper mills and sawmills. An assessment of the impact of forest management constraints on mills would require detailed, and often propriety, price data on wood supplies and so was beyond the scope of this study. Such an assessment would have to be able to factor out important market drivers such as overall wood products demand and product price competition both within and beyond Wisconsin.

Zander Evans (top)
Andrew Meier (lower)

An assessment of all the economic forces affecting the logging industry is outside the scope of this study. However, our listening sessions and our surveys of timber professionals reinforce the widely voiced view that timber professionals are shouldering a disproportionally large portion of the costs of forest management constraints even though forest owners, primary and secondary wood-using businesses, and the general public all benefit from healthy, productive forests. The reasons for this disparate cost for timber professionals are complex. However, a significant factor may be that while timber professionals are required to adjust their practices substantially to implement or comply with harvest constraints, they are often unable to adjust their pricing to account for increasing costs or reduced efficiency of production because their delivered prices are set by receiving mills, and many feel they have little to no margin to lower stumpage prices below prevailing rates.

Future efforts to weigh the economic costs of forest management constraints would benefit from more detailed recordkeeping of the outcomes of applying the constraints. The most effective scale for measuring the impacts of constraints on timber harvesting is the stand or sale level because those are the scales at which constraints are applied. To be useful, sale records should include detailed descriptions of which constraints were applied, why they were applied, where they overlap or mask another constraint, and the sale price data.

ECOLOGICAL CONSEQUENCES

In general, the forest management constraints regarding harvest and treatments for tree diseases are expected to have positive repercussions on forest composition, structure, and productivity, particularly over the long term. For example, winter harvesting constraints promote forest health by protecting soil structure, integrity, and health, and also promote understory and ground cover diversity. These variables often are correlated with enhanced tree regen-

Zander Evans

eration. A diverse, healthy forest, in turn, provides habitat for a greater variety of wildlife than a forest in poor condition. Constraints that reduce harvesting in spring and early summer generally benefit a wide range of wildlife and protected species in the short term by avoiding direct impacts to habitat during the predominantly May through July breeding season. Constraints such as winter harvest and riparian buffer zones, which are implemented to prevent sediment inputs into nearby water bodies, have a positive effect on water quality, but their effect may be equal to the positive effect of water quality BMPs.

While all the harvesting constraints and best practices we studied are based on science and are developed with scientific input, little research is available on the efficacy of constraints as they are applied. A notable exception is the application of water quality BMPs, which research has shown to be effective. New scientific research on the effectiveness of forest management constraints at achieving their intended outcomes would provide valuable information on the benefits to forest productivity, wildlife habitat, and biodiversity.

Rigorous scientific study could also help improve forest management recommendations and constraints so that they provide the best balance of harvest limitations and protections for other forest values. For example, the best way to improve the current recommendations for oak wilt would be to improve our understanding of oak wilt dynamics through scientific study. Without detailed research, changes to forest management constraints may result in unintended economic costs, or may burden timber harvests with costs that do not result in effective protection of forest values. Moreover, since most foresters and timber professionals apply constraints because of their professional judgement, changes to official guidance may not result in changes on the ground unless based on sound science accepted by forestry professionals.

Mike Lynch

CONCLUSION

We carefully reviewed the existing scientific literature, mapped affected areas, analyzed harvest cases studies, conducted surveys of foresters and timber professionals, modeled economic effects, and assessed ecological impacts to understand consequences of constraints that affect forest management in Wisconsin. Through this process, we found forest management constraints can have a large impact for some individuals and forest-based businesses in Wisconsin, particularly timber professionals. Based on our assessment, forest management constraints driven solely by regulations have a lesser impact on forestry operations relative to impacts from other factors. Seasonal constraints for soil, water, and forest health protection have the largest impacts; they are also generally supported by foresters and timber professionals, and have the most direct economic effect on long-term forest productivity.

Based on our harvest case study data and scoping assessment of the most important constraints, we estimated that the most plausible economic modeling scenario was a one-month increase in the logging season, which we further estimated to be between five to ten percent of the existing logging output. It is important to acknowledge that our modeling did not include impacts to forest landowners, pulp and paper mills, or sawmills. Other model assumptions or the inclusion of other sectors would produce significantly different results.

The economic benefits of removing or adjusting forest management constraints should be weighed against the benefits of forest values (including non-monetized ecosystem services) that are protected by constraints. Those benefits are less tangible and less easily measured, but they are no less important and are widely valued by society and by taxpayers who support forestry programs.

Our detailed review of the potential ecological impact of forest management constraints indicates they are, on the whole, expected to have positive repercussions on forest composition, structure and productivity particularly over the long term. We did not find significant evidence, either in our literature review or in our surveys and interviews with practitioners, that forest practices restrictions are ineffective or inappropriate for their intended purpose of protecting forest health, productivity, and non-timber values. In general, there is limited research on the efficacy of forest management constraints, with the notable exception of water quality BMPs. Field-based research into the effectiveness of Wisconsin's forest management constraints in achieving their intended outcomes would help fill this gap.

The localized impacts of harvesting constraints vary across the seasons and geography and are felt by timber professionals, foresters, forest-based businesses, and woodland owners. Any proposed changes to this balance should carefully consider the relationship between ecology, economy, and societal values, and the allocation of costs and benefits between affected parties and across different time scales.

Alex Finkral

Andrew Meier

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APPENDIX I – SURVEY QUESTIONS

Please see
www.forestguild.org/publications/research/2016/WFPS_AppendixI.pdf

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APPENDIX II – ECOLOGICAL ANALYSIS

Please see
www.forestguild.org/publications/research/2016/WFPS_AppendixII.pdf

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The Forest Stewards Guild practices and promotes ecologically, economically, and socially responsible forestry as a means of sustaining the integrity of forest ecosystems and the human communities dependent upon them. Our members are foresters, conservationists, resource managers, scientists, students, forestland owners, policy makers, and land stewards working in forests throughout the United States and Canada. Our research program synthesizes existing knowledge and conducts novel scientific studies as a complement to Guild member's place-based experience.

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