Final Report

THE SCALE AND COST OF SEASONAL TIMBER HARVESTING RESTRICTIONS IN WISCONSIN

Michael Demchik, Joseph Conrad, Melinda Vokoun

University of Wisconsin-Stevens Point

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Introduction

Today's timber markets are global in scope, and therefore Wisconsin's wood supply chain, which consists of private and public landowners, loggers, and mills must produce wood at globally competitive prices. Regulations and restrictions imposed on Wisconsin's wood supply chain have the potential to reduce stumpage prices on sales with restrictions and increase them on sales without them, increase timber harvesting costs, alter timber procurement practices, and increase the cost of delivered wood to mills. Because regulations have the potential to affect Wisconsin's forest products industry's ability to compete in the global marketplace, it is important to understand the costs and benefits of regulations and their impact on Wisconsin's supply chain.

Risk abatement is one of the oldest concepts in economics. There is an expanding literature on the application of economic models of risk abatement to harvest regulations (specifically those impacting endangered species and wetlands). Bauer et al. (2010) showed wetland regulations did not provide as much benefit when the surrounding habitat matrix was not considered. They found that the impact of wetland protections on amphibian populations varied significantly based on surrounding land use and that marginal costs varied by the level of habitat usage expected by the organism. Haight (1995) found a significant increase in cost of conservation as the stringency for an extinction risk criteria increased; indeed, Marshall et al. (2000) specifically considered the outcome of endangered species management to be subject to uncertainty. For this reason, both authors suggested that species conservation is subject to risks that can be modeled in a similar manner to other risks. Indeed, small increases in certainty of species survival can have significant costs; in the case of the northern spotted owl (*Strix occidentalis caurina*), a four percent increase in chance of survival was estimated to cost $13 billion (Montgomery et al. 1994). Functionally, it is impossible to eliminate risk of extinction, no matter how much money is spent or the number of regulations that are in place; therefore, resource managers and government agencies must determine an appropriate level of risk reduction, because small changes in risk often come with extreme changes in costs. Determination of acceptable levels of risk that allow efficient application of resources reduces the opportunity cost of protecting these resources (Shogren et al. 1999). While application of economic models to protection of endangered resources is still new, effective determination of tolerable risk appears to be the main factor that needs to be addressed when making decisions about policy approaches to protection.

Seasonal timber harvesting restrictions are imposed on many timber sales in Wisconsin, ostensibly, to protect the forest resource. Timber sales on wet sites may include contract stipulations that limit timber harvesting to the winter months when the ground is frozen to reduce the risk of soil damage (e.g. Wausau and Marathon County Parks, Recreation, and Forestry Department 2015). Other sales may require that pine (*Pinus spp.*) stumps be treated with fungicides during the spring, summer, and fall to prevent annosum root rot (*Heterobasidion annosum*). A common restriction is to prohibit the harvesting of stands with at least 15 ft^2 ac^{-1} of oak (*Quercus spp.*) basal area between either April 1st or April 15th and July 15th, depending on the location within the state (Wisconsin Department of Natural Resources [WDNR] 2015b). This restriction, coupled with seasonal weight restrictions on many public roads in Wisconsin (Wisconsin Department of Transportation 2015), effectively keep these stands off limits to harvesting from mid-March through mid-July, or one-third of the calendar year. While the motivation for these restrictions is clearly to protect the forest resource, these restrictions may increase costs to the wood supply chain and make the state's forest industry less competitive with other regions and countries.

Voluntary and mandatory timber harvesting regulations, including seasonal restrictions, tend to increase timber harvesting costs directly by requiring certain practices and indirectly by reducing productivity and utilization. A study of bid results from 473 timber sales in Minnesota found that sales that were restricted to winter harvesting received bids that were, on average, $65.82 per acre lower than sales that could be harvested outside the winter months (Barron et al. 2015). In 2001, large loggers in Arkansas spent an average of 23 hours and $1,562 implementing BMPs on their average harvest (Montgomery et al. 2005). Seventy-five percent of responding Minnesota loggers reported increased costs as a result of voluntary BMP implementation in the early 1990s (Blinn et al. 2001). Previous research in the U.S. South and Maine found that mill quotas, weather, and other constraints resulted in logging capacity utilization of just 65% and this inefficiency cost the wood supply chain $430 million annually, or $1.66 per ton of delivered wood (Greene et al. 2004). By comparison, many pulpmill managers believe that a mill should operate at 90% of capacity to maintain an adequate profit margin (Todd and Rice 2005). In the study by Greene et al. (2004), the impact of regulations was minimal; however, BMPs have tightened since this time and Wisconsin has a number of recommended practices such as oak wilt restrictions, leaf-off restrictions for aspen (*Populus* spp.), and other recommended practices that were not in place in the aforementioned study.

Timber harvesting restrictions, including seasonal restrictions, have the potential to reduce stumpage prices. Dahal and Mehmood (2005) found that, in Arkansas, timber sales without wet weather restrictions received bids that were $163 per acre higher than sales with wet weather restrictions. Likewise, this study found that timber sales offered during the winter, spring, and summer received lower bids compared to sales offered during the fall. In Arkansas, fall is the driest season, and therefore harvesting is less likely to be interrupted by inclement weather during the fall. In Minnesota, timber harvest guidelines reduced bidders' willingness to pay by 10% ($2.66 per cord) (Kilgore and Blinn 2003). The restrictions having the greatest impact were related to leave tree retention, skid trail placement, and logging slash distribution (Kilgore and Blinn 2005). In Wisconsin, spring breakup, road restrictions, and oak (*Quercus* spp.) harvest restrictions are likely as important as these other restrictions.

Seasonal timber harvesting restrictions have the potential to increase timber procurement costs. Todd and Rice (2005) identified five major factors that influenced procurement patterns and inventory levels at northeastern pulpmills: consumer demand for paper, wood availability, wood cost, weather, and contracts with suppliers. Seasonal restrictions limit wood availability during certain periods of the year and encourage mills to increase inventories prior to seasonal restrictions taking effect. In Maine, mill inventories peak in March because of wet weather in spring (Todd and Rice 2005). Seasonal restrictions impact the supply chain in a similar manner to weather by restricting access to timber, or some species of timber, for certain periods during the year. Therefore, mills would be expected to respond to seasonal restrictions in the same way that they respond to weather-related supply limitations. Maintaining high inventory levels is not without costs. High inventory levels result in large amounts of capital being tied up in an unproductive capacity for long periods of time and also require large storage space, which increases operating costs (Lang and Mendell 2012). However, maintaining low inventories during periods of constrained harvest activity is not cost-effective either because timber prices often increase as weather restrictions approach (Todd and Rice 2005). Additionally, because timber quality degrades while in storage, mills not only face holding costs, but also a loss in value of the inventory over time.

Timber harvests in Wisconsin are commonly subject to seasonal restrictions imposed with the goal of maintaining forest health and protecting state-listed species. The combined impact of these restrictions may limit the availability of timber during portions of the year, reduce stumpage prices, increase timber harvesting costs, and alter timber procurement practices; furthermore, the ecological impacts of these restrictions are poorly understood. Therefore, the goals of this study were to: 1) identify the most commonly imposed seasonal restrictions and the degree to which seasonal restrictions vary by geographic area, soil type, and forest types in Wisconsin; 2) estimate the cost of seasonal restrictions to loggers, forest landowners, and the forest products industry; and 3) summarize the known ecological consequences of seasonal timber harvesting restrictions.

Methods

Timber sale analysis

During the spring and summer of 2015, data was requested from the Wisconsin DNR for all timber sales held on State Lands as well as randomly selected sales on County Forest land and private lands under Managed Forest Law (MFL) in Wisconsin. This data search was constrained to all sales which were closed in the year 2013. Additionally, data for sales on private lands not involved with MFL was requested from industrial foresters. We were able to collect complete data for 184 sales on State Land, 100 sales on County Forest land, 105 sales on privately owned lands enrolled in the MFL program, and 56 sales on privately owned lands not enrolled in the MFL program. The total database was composed of 445 timber sales. For all of these sales, we determined whether their harvest was seasonally restricted and for what reasons. Reasons for seasonal harvest restriction were classified into:

- Access/transportation
- Hunting
- Oak wilt harvest season restriction
- Recreation conflict
- Soil/hydrologic disturbance
- Rare/threatened/endangered species.

Using a combination of various data sources (the Wisconsin Forest Inventory and Reporting System, the Timber Sale Notice and Cutting Report and individual calls to foresters), we classified the primary forest cover into upland hardwood, lowland hardwood, upland conifer and lowland conifer. Using the NRCS SSURGO database, we sorted the soils into sandy, loamy, clay, wetland or mixed (mixed included significant areas of both upland and wetland soils). Using the 22 Wisconsin Geographic Management Units, we sorted the sales into broad regions.

While many sales had specific dates for seasonal restriction, often sales were restricted to “frozen” or “dry” or “frozen or dry”. For this reason, we assigned available periods to these restrictions. Sales listed as “frozen or dry” or “dry” were assumed to be available during August 1 – March 15 and sales listed as “frozen only” were assumed to be available during December 1 – March 15. However, these categories are weather-dependent with some years having greater or lesser availability. All others dates for seasonal restriction were included as listed in the documentation received.

To analyze the impact of seasonal timber harvesting restrictions on actual bidding behavior, we analyzed timber sale prospectuses and bid results from the Wisconsin County Forests. We contacted the county forest administrator or a staff forester from each of the 29 county forests in Wisconsin and requested all prospectuses and bid results for sales in 2014. We received data from a total of 660 timber sales from 28 of the 29 counties. The highest bids ranged from $0 (failed to sell) to over $7,000 per acre. Because there were very few sales at the extreme ends of this range and because sales with very high value timber are less likely to be affected by variables such as seasonal timber harvesting restrictions, we removed sales with high bids less than $200 per acre or greater than $3,000 per acre. This reduced the dataset to 597 timber sales. After removing additional outliers, our final dataset consisted of 570 timber sales.

We analyzed the impact of seasonal timber harvesting restrictions and other variables using multiple linear regression in SPSS (IBM Corp. 2012). The dependent variable for the model was the winning bid price per acre. Our initial model used the following predictor variables: acres in the timber sale, hardwood volume percent (percent of total sale volume), softwood volume percent, aspen (*Populus spp.*) volume percent, tons per acre in the timber sale, quarter that the sale was offered (one dummy variable for each quarter with the variable equal to 1 if the sale was offered in that quarter and 0 otherwise), a seasonal restriction that limited harvesting to winter or frozen ground (dummy variable equal to 1 if this restriction was applied, 0 otherwise), and a seasonal restriction that did not restrict harvesting to winter or frozen ground (dummy variable equal to 1 if this restriction was applied, 0 otherwise). For the species percent (hardwood, softwood, or aspen) variables, softwood percent served as the reference variable. For the quarter variables, the second quarter served as the reference variable. All of the variables were included in the initial model and variables that were not significant were removed sequentially using a backward elimination approach ($\alpha = 0.10$). We compared the number of bids received on timber sales with a winter or frozen ground restrictions to sales without this restriction using a two-tailed independent samples t-test ($\alpha = 0.05$).

Forester survey

We conducted a survey of public and private sector foresters in Wisconsin in collaboration with the Forest Guild to estimate the frequency of seasonal timber harvesting restrictions and foresters’ perceptions of their cost and effectiveness. The survey was conducted using a modified version of the Tailored Design Method (Dillman 2007). The survey was conducted online using SurveyMonkey. Private sector foresters received a prenotice letter via first-class mail and three email invitations with a link to the questionnaire on three consecutive Mondays beginning in early August 2015. One forester did not have an email address and was sent a paper copy of the questionnaire. Public sector foresters had been contacted regarding another portion of the study, and therefore they received the three emails with links to the questionnaire, but were not sent a prenotice letter.

One hundred eighty-four private sector foresters were identified using a published list of WDNR cooperating foresters (WDNR 2015a). One hundred ninety-seven public sector foresters were identified from the State of Wisconsin (155), the Wisconsin County Forests (29), and the USDA Forest Service (13). The state representatives included all Wisconsin Department of Natural Resources foresters, while the county representatives included the county forest administrator from each county, and the federal representatives included the forest and district-level silviculturists and timber program managers.

The questionnaire included twenty-seven questions. Of the twenty-seven questions, ten were open-ended, nine were five-point Likert scale, and eight were closed-ended. For Likert scale questions, 1 = strongly negative response, 2 = negative response, 3 = neutral, 4 = positive response and 5 = strongly positive response.

The two-tailed t-test was used to test the null hypothesis that the mean response was neutral versus the alternative that the mean response was different from neutral on five-point Likert scale questions. The two-tailed two sample t-test assuming unequal variance was used to compare the responses of two populations (e.g. public vs. private sector foresters). Analysis of Variance and the Tukey HSD test were used to estimate whether the mean responses varied between three or more populations (e.g. consulting, industry, and public sector foresters). The Levene's test for equality of variance was used to test the assumption of equality of variance. If the variance was not equal between populations, the data were transformed logarithmically prior to analysis. If the variance was unequal after the transformation, the Welch's ANOVA and the Games-Howell test were used (Maxwell and Delaney 2004). All statistical tests were conducted at the 5% significance level and all statistical analysis was performed using SPSS (IBM Corp. 2012).

Non-response bias was tested using wave analysis (Armstrong and Overton 1977). We compared the responses received between the first and the second invitations to those received after the second invitation on the percentage of sales with soil disturbance, oak wilt, and access restrictions using an independent samples t-test at the $\alpha = 0.05$ level. There were no significant differences between the frequency of access restrictions (P=0.06), oak wilt restrictions (P=0.65), or soil disturbance restrictions (P=0.88) between early and late responders, which suggests that non-response bias was not an issue with this sample.

One email could not be delivered and three recipients were no longer in business or suggested that the survey was not applicable to them, which reduced the overall sample size to 377. A total of 245 questionnaires were completed, yielding an adjusted response rate of 65.0%. Fifty-seven percent of respondents classified themselves as public agency foresters, 25% were consulting foresters, 10% worked in forest industry as procurement foresters or landowner assistance foresters, while the remaining 8% did not specify their position.

Mill survey

We conducted a mail survey of mills in Wisconsin to document their procurement practices and analyze how seasonal timber harvesting restrictions affect their business. The survey was conducted during the late summer and early fall of 2015 using the Tailored Design Method

(Dillman 2007). A list of 165 mills was obtained from USDA Forest Service Forest Inventory and Analysis (FIA) data, Wisconsin's Wood Using Industry Online database (University of Wisconsin-Madison et al. 2006), and personal contacts with Wisconsin Department of Natural Resources forest products specialists.

The questionnaire consisted of 38 questions. Twenty questions were open-ended and generally requested quantitative data, ten were Likert scale, and eight were closed-ended. For Likert scale questions, 1 = strongly negative response, 2 = negative response, 3 = neutral, 4 = positive response and 5 = strongly positive response.

Because of the small sample size for this survey, we compared responses between mill types using the Kruskal-Wallis test and the Dunn-Bonferroni post-hoc procedure to compare populations. All statistical tests were conducted at the 5% significance level and all statistical analysis was performed using SPSS (IBM Corp. 2012). For five-point Likert scale questions, we calculated a confidence interval for the mean response from each group and if the confidence interval did not overlap with the neutral response ($\bar{x}$ = 3.00), that response was reported as statistically different from neutral.

To analyze the changes in inventory levels resulting from seasonal restrictions, we asked responding mills to report the days of inventory that they currently hold in each quarter and the number of days of inventory that they would hold in the absence of seasonal timber harvesting restrictions. We calculated a 95% confidence interval for the difference between the two responses, and if the confidence interval did not overlap with zero, this was reported as a significant difference.

We applied a finite population correction factor when calculating confidence intervals for each mill type (Scheaffer et al. 2006). We estimated that there were fifteen pulpmills (including composite mills), 130 small sawmills, and seventeen medium and large sawmills in Wisconsin. Companies that owned multiple mills, but purchased timber as a single entity, were counted as a single entity.

Twenty-three facilities were removed from the sample because the survey could not be delivered, the facility had closed, or the facility did not purchase its own timber. Sixty-three questionnaires were returned, of which 55 contained usable data, which yielded an adjusted response rate of 39.0%, which is consistent with past studies (e.g. Anderson and Germain 2007, Egan et al. 2007). Respondents included twenty-nine hardwood sawmills, seven softwood sawmills, ten sawmills that processed both hardwood and softwood species, six pulpmills, two composite mills, and one "other" mill. For analysis, the respondents were concatenated into the following categories: small sawmills (purchased <50,000 tons of timber per year), medium and large sawmills (50,000+ tons per year), and pulpmills (including composite mills and pellet mills).

Respondents purchased a combined 7.7 million tons of wood annually, representing approximately three-quarters of the growing stock volume harvested annually in Wisconsin (Perry 2015). This suggests that many of the nonrespondents were closed, or were small, hobby-type mills. Because of the large percentage of the processed volume accounted for in this study, nonresponse bias should not be of concern.

Cost estimates

In order to estimate the cost of treating stumps to prevent annosum root rot, we contacted several logging businesses and requested information regarding the cost to equip harvesters to treat stumps, maintenance costs, the cost to obtain a pesticide applicator's license, the cost of cellu-treat, and the amount of cellu-treat typically applied per acre or per unit volume. We combined this data with production data collected as part of the Wisconsin Forest Practices Study (Prisley et al. 2014-2015) to estimate the cost per ton for loggers to treat stumps. For this analysis, we selected production data from four logging crews, with one crew representing each of the following types of crews: above average production, but a low percentage of softwood harvested; above average production and a high percentage of softwood harvested; below average production and a low percentage of softwood harvested; and below average production and a high percentage of softwood harvested.

To calculate the total cost to treat the stumps, we estimated the range of fixed costs and variable costs per ton. We assumed an economic life of six years for the harvester (Brinker et al. 2002) and that the Cellu-Treat application mechanism had the same life as the machine. We divided the up-front fixed cost for equipping the harvester to treat stumps by six, added annual maintenance cost, and divided that value by the number of tons of softwood harvested annually to estimate the fixed costs per ton to treat the stumps. The variable cost of the Cellu-Treat chemical was given to us by logging businesses. We converted costs provided on a per-acre basis to cost per ton using the average number of tons per acre available from the 2014 county forest timber sales that consisted of at least 75% softwood. We then combined the fixed costs per ton to the variable cost per ton of Cellu-Treat to estimate the total cost per ton. For this analysis, we provided a low cost per ton and a high cost per ton to treat stumps. The low value was estimated by using the low end of the range of costs provided by loggers and the high value was estimated by using the high end of the range of costs provided. For this analysis we assumed that the logger operated for 46 weeks per year.

In order to demonstrate how seasonal timber harvesting restrictions may impact loggers, we used production data collected as part of the Wisconsin Forest Practices Study (Prisley et al. 2014-2015) along with machine rate estimates to simulate logging revenues and expenses when harvesting varies seasonally. We calculated an average cost for owning and operating a typical cut-to-length system using the machine rate method and published assumptions (e.g. Brinker et al. 2002). We assumed a purchase price of $550,000 for a harvester and $370,000 for a forwarder. We assumed that fuel consumption was 5.3 and 4.5 gallons per productive machine hour for the harvester and forwarder, respectively. For each machine, we assumed a salvage value of 20% of the purchase price, an economic life of six years, a fuel cost of $2.45 per gallon for off-road diesel, a lubrication rate of 36.8% of the fuel cost, maintenance and repair equal to 30% of depreciation, and utilization of 80%. We assumed that there were two operators on the crew that were paid $15 per hour (Bureau of Labor Statitistics 2014) plus 40% overhead and fringe. Using this approach, we were able to estimate fixed, variable, and labor costs for owning equipment and operating a logging crew. Fixed costs were assigned equally to each of the four seasons of the year, while variable and labor costs were assigned based on the hours worked in each season. For this analysis, we assumed that the logging crew generated revenues of $20 per ton of timber harvested after stumpage payments and hauling costs are subtracted. Profit by season was calculated by subtracting total costs from total revenues generated in each season.

We analyzed the potential profit earned by season under three scenarios: 1) a scenario in which loggers are most productive during winter (as was the situation during 2014-2015), 2) a scenario in which timber harvesting efficiency is uniform between seasons at the level achieved during the fall and winter of 2014-2015, and 3) a no summer harvest scenario in which no timber is harvested between mid-March and August 1st. The current situation is that loggers are most productive during the winter months. Efficiency is similar during fall and winter, but is lower during spring and summer. The second scenario simulates a situation in which loggers worked the same number of hours per week during each season as they did during 2014-2015, but efficiency was uniform at the level achieved during the fall and winter across the four seasons of the year. The final scenario is one in which all timber sales were seasonally restricted and no timber could be harvested between mid-March and August 1st. This analysis is intended to demonstrate the impact that seasonal variation in timber availability may impact loggers; it is not meant to provide exact cost data for an individual logger. Actual logging costs will vary considerably between crews based on the type of timber harvested, site conditions, age and type of equipment, and other factors.

Results and Discussion

Scale of seasonal harvesting restrictions in Wisconsin

Percent of sales restricted

Generally, a very large number of sales were subject to some form of restriction. During some months, less than half of the sales were available for harvest (Table 1). During the months of April, May, June, and July more than half of the sales we sampled were unavailable. MFL sales were most likely to be restricted during this period. This is surprising because public lands are often purchased to provide specific ecosystem services (for example, purchases of headwaters to preserve water quality or the purchase of critical habitat) and because harvests on these lands are often subject to significant public scrutiny. Our forester survey found a tendency of consulting foresters to restrict timber harvests at a higher rate than public foresters. While this is likely the source of the greater seasonal restrictions for MFL parcels, the reason that these foresters choose to restrict at a higher rate is still an open question.

Overall, 67% of the sales we sampled were restricted seasonally in some way (Table 2). The percentage of sales restricted was consistently high across the state (Figure 1). The main reasons for seasonal harvest restriction were soil/hydrologic disturbance (44%), access/transportation issues (18%), oak wilt (18%), rare/threatened/endangered species (8%), recreation conflict (6%) and hunting (2%) (Table 2). The values in Table 2 exceed 100% because some sites were restricted for multiple reasons. While having a “NHI detection” (finding that the site may host a rare/threatened/endangered species that is listed in the Natural Heritage Inventory) was quite common on these sites (overall, 45% of sales had a NHI detection), the vast majority did not result in a seasonal restriction. Overall, only 8% of sales were seasonally restricted for this reason. Of most consequence were wood turtle (*Glyptemys insculpta*) or Blanding’s turtle (*Emydoidea blandingii*), which resulted in restrictions on 3% of sites. Northern goshawks (*Accipiter gentilis*) and Karner blue butterflies (*Lycaeides melissa samuelis*) resulted in restrictions on less than 1% of sales each. Bats were listed as NHI hits on three sites, but none resulted in a seasonal restriction. Of course, the timber sales that were analyzed were conducted prior to the federal listing of the northern long-eared bat (*Myotis septentrionalis*). Overall, NHI detections were of much less importance to seasonal harvest restriction than originally expected.

Table 1: Percent of timber sales available by month and ownership. Note: some of the sales listed as available during December through March may not actually be harvestable during the entire period depending on weather conditions. MFL = Managed forest law.

	Month											
Ownership	1	2	3	4	5	6	7	8	9	10	11	12
State	100	100	75	52	52	52	56	87	87	87	87	100
County	99	99	72	43	43	44	46	67	67	67	67	100
MFL	100	100	67	31	30	30	32	59	61	61	61	100
Non-MFL	100	100	88	77	77	77	77	91	91	91	91	98
Total	100	100	74	47	46	47	49	73	73	73	73	100

Table 2: The percentage of total sites with seasonal harvest restrictions due to each classification of reasons sorted by landowner classification.

Reason for Seasonal Restriction	State	County	MFL	Non-MFL	Overall
Soil/hydrologic disturbance	36	45	63	30	44
Access/transportation	22	12	14	20	18
Oak wilt harvest season restriction	23	16	10	14	18
Rare/threatened/endangered species.	14	1	3	5	8
Recreation conflict	11	2	3	9	6
Hunting	1	0	4	1	2
All reasons	72	66	75	55	67

Contrary to expectations, the percentage of sales in lowland and upland forest cover types with seasonal restrictions were not largely different (79% and 70%, respectively). This was likely due to the nature of the classifications we used. Because some species (i.e. black ash [*Fraxinus nigra*]) can grow in wetland and moist upland positions, it was difficult to separate lowland from upland sites. All sales in lowland hardwoods and conifers on wetland soils were restricted (although this was represented by only 4 sales) and 75% of those on mixed soils (both upland and wetland soils on the sale) were restricted.

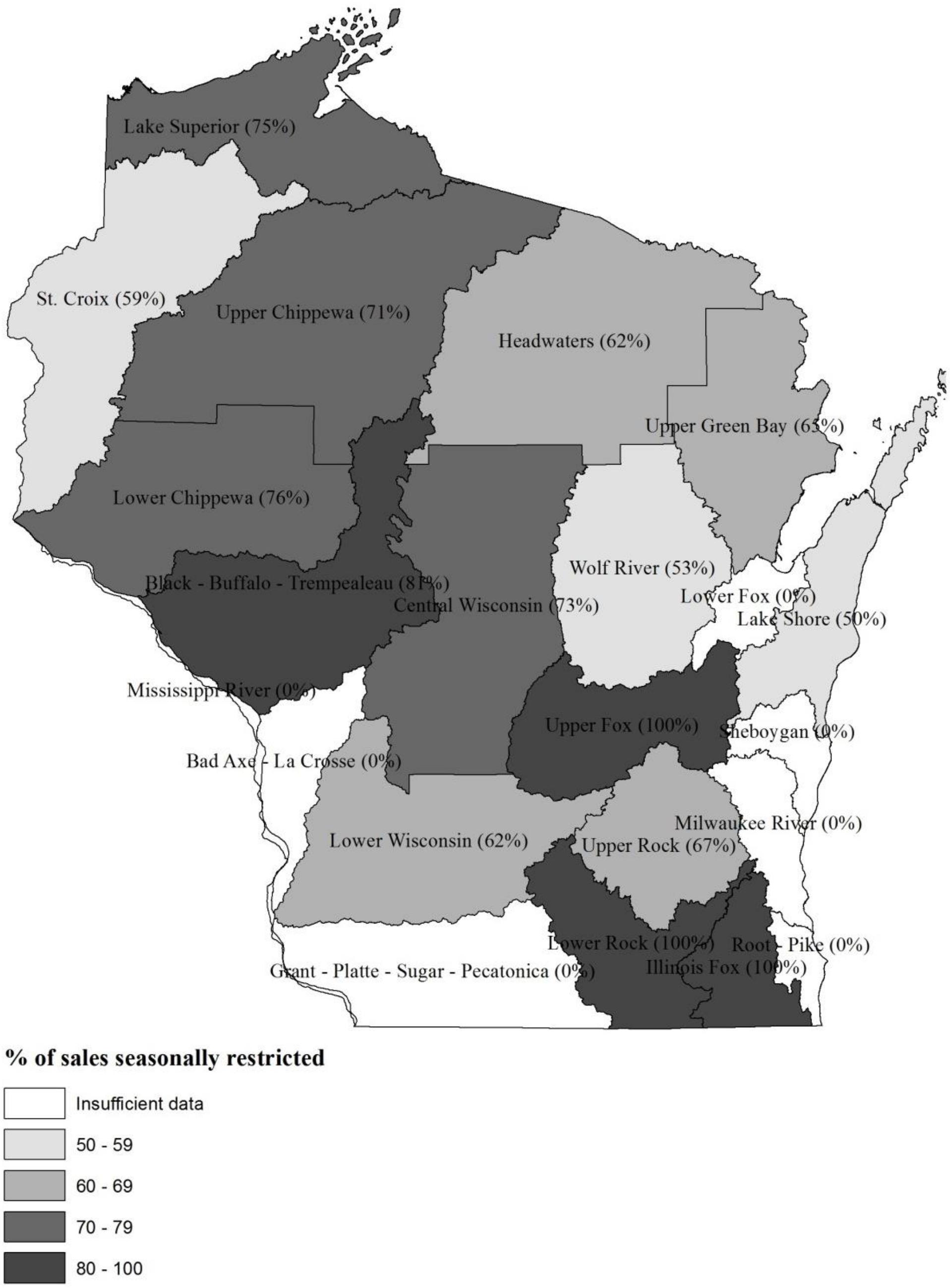

Figure 1: The percentage of sales with seasonal harvest restrictions by geographic management unit across all ownership classes.

Results of the forester survey support findings of the timber sales analysis. Restrictions to prevent soil and hydrological damage were applied to more than half of timber sales in the state by all three groups of foresters (Figure 2). Oak wilt restrictions were applied to nearly 40% of timber sales, which implies that nearly all stands with a significant oak component were restricted from harvest between early to mid-April and mid-July (WDNR 2015b). Foresters reported applying oak wilt restrictions more frequently than our analysis of timber sales indicated. There are two possible reasons for this discrepancy. First, there may have been a greater percentage of oak sales prepared by respondents than was analyzed in our study. Second, some of the sales that we analyzed may have been restricted for some other reason (i.e. access or soil/hydrology) that prevented harvesting during April-July anyway, and therefore oak wilt may not have been cited as the reason for the restriction, even though the oak wilt restriction would have been applied in the absence of the other restriction.

Commonly applied restrictions

Access/transportation, oak wilt, recreation, and soil disturbance restrictions accounted for four of the six most frequently applied restrictions, and all of them are seasonal in nature and may significantly affect timber supply (Figure 2). While restrictions related to annosum root rot, biomass harvesting guidelines, and invasive species BMPs may impose a cost on loggers and timber buyers, they do not automatically restrict timber harvesting during a given time of the year. In contrast, soil disturbance and access/transportation restrictions may limit operations to frozen ground conditions and oak wilt restrictions restrict harvesting for three months each year, and since these restrictions come on the heels of spring break-up weight restrictions on public roads, many oak sites may effectively be restricted from mid-March through mid-July. Recreation-related restrictions may take many forms, but a commonly applied restriction prevents stands from being harvested during deer season. It is conceivable that an oak stand could be restricted due to oak wilt and spring break-up from mid-March through mid-July and by recreation from mid-September to early January, which would leave only four and one-half months to conduct the harvest. This set of restrictions could also have significant forest regeneration impacts, because harvest during acorn drop during the fall generally improves oak regeneration because the soil is scarified and the acorns are better distributed across the site.

Recreation restrictions were cited more often by foresters than we detected in our timber sale analysis. One explanation for this is that sites restricted for other reasons (e.g. access or soil/hydrology) also would have been restricted for recreation-related reasons if it was not already restricted for some other reason. It is also likely that the hunting season restriction was simply not required often on public lands and was not listed in the paperwork for MFL lands, as it is not required in the cutting notice prepared for the Wisconsin DNR, and was simply added to the timber sale contract when prepared by the forester or logger.

The requirement to treat stumps to prevent annosum root rot was reported more commonly by survey respondents than in the timber sale analysis. This is probably because the sales that we analyzed were closed in 2013, meaning that they were set up prior to the 2013 publication of state guidelines to prevent annosum root rot (WDNR 2013). This is also, strictly speaking, not a seasonal restriction because these sites can be harvested any time during the year as long as the stumps are treated. The annosum restriction offers loggers and timber buyers the choice between a seasonal restriction and an added cost.

Foresters reported a greater percentage of sales restricted because of rare or endangered species than we found in the timber sale analysis. This would have occurred if some respondents included the percentage of their sales with a NHI detection, even if the detection did not lead to a restriction. Nearly half of the timber sales that we analyzed had a NHI detection, but only 8% of the sales were restricted because of the detection. This difference may be an issue of perspective, in that the foresters may view a NHI detection as a restriction, even if they do not actually have to alter the harvest to accommodate the species. It is also possible that the foresters did not pursue the species occurrence further since the harvest was already restricted to outside of the relevant time period for some other reason (e.g. access or soil/hydrology).

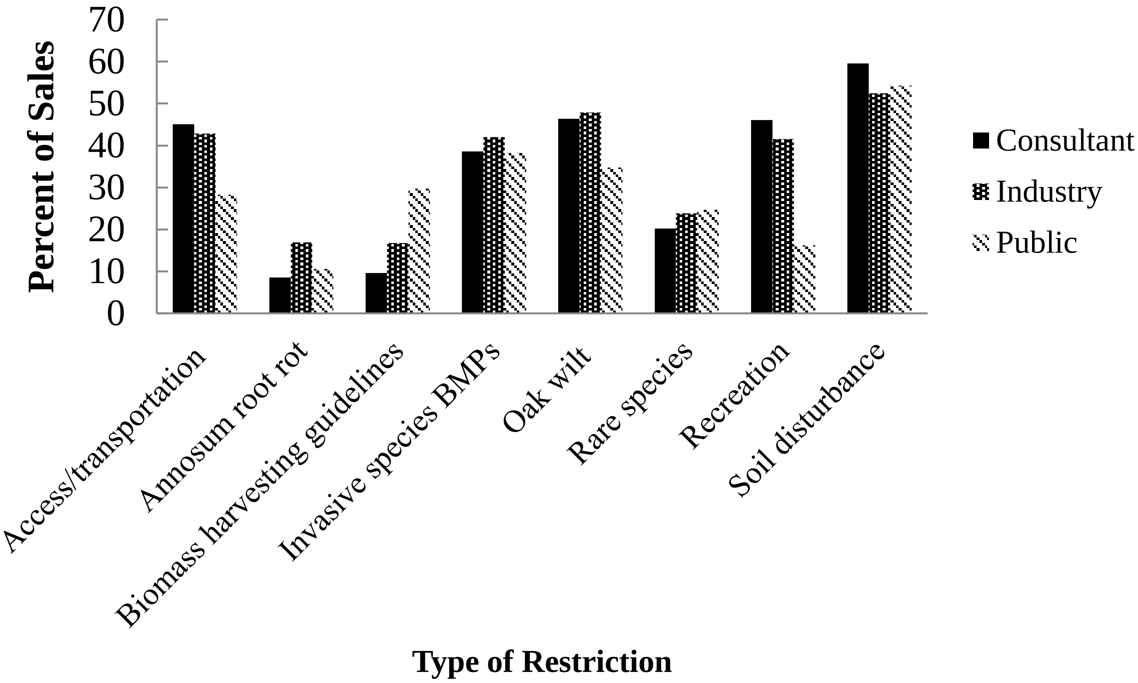

Figure 2: The frequency with which the eight most commonly applied timber harvesting restrictions are required on timber sales by consultants, industrial, and public sector foresters.

Consulting foresters were more likely to apply an access/transportation restriction than public sector foresters (p=0.03) (Figure 2). Public sector foresters were more likely to require that biomass harvesting guidelines be followed on a sale than consulting foresters (p<0.01). Consulting foresters were more likely than public sector foresters to apply recreation-related restrictions to timber sales (p<0.01). Differences between industry foresters and the other two types of foresters were not significant.

Rationale for restrictions

The most commonly cited motivation for applying timber harvesting restrictions was professional judgment, which was one of the top two reasons cited for nine of the eleven restrictions listed (Table 3). Landowner goals was the primary motivator for applying recreation restrictions and access/transportation restrictions. This is logical because recreation-based restrictions do not necessarily protect water or site quality, but do affect the landowner's enjoyment of the property and access restrictions may have as much to do with aesthetics and landowner preference as they do with resource protection. Program requirements, such as MFL, were the third most common motivating factor, and were cited as a primary motivator for cultural/archaeological restrictions, invasive species, oak wilt, and water quality BMPs.

Motivations for applying restrictions were generally consistent between forester types; however, there were some discrepancies (Table 3). For example, forest certification was the primary motivation for restricting harvest to reduce soil disturbance for 63% of industry foresters and 72% of public sector foresters, but only 39% of consulting foresters. A similar pattern was observed as it relates to rare species protection and forest certification requirements for which 58% of industry foresters and 50% of public sector foresters cited this motivation, while only 36% of consulting forester cited this motivation. Fewer consulting foresters cited state and federal Endangered Species Act regulations (60% and 52%) than industry foresters (71% and 71%) and public sector foresters (75% and 68%).

While many BMP's are non-regulatory, through forest certification or professional certification (e.g. Master Logger program) these voluntary BMP's become functionally mandatory. Often, forest certification and professional certification programs require that logging operations follow all BMP's, making "voluntary" BMP's that allow for judgments about reasonable operability functionally mandatory with failure to apply BMP's carrying significant ramifications. Because of the proliferation of voluntary BMPs (e.g., biomass harvesting guidelines, invasive species BMPs, etc.) the cumulative impacts of their application may not be fully understood.

Seventy-eight percent of pulpmills and 63% of small sawmills reported that seasonal timber harvesting restrictions were common on private forestland in Wisconsin. Likewise, 100% of pulpmills and 72% of small sawmills reported that seasonal restrictions were common on state and county timber sales in Wisconsin. These views were supported by the analysis of timber sales on public and private land in Wisconsin (Table 1).

Table 3: The top two reasons cited by foresters for applying ten timber harvesting restrictions and the percentage of respondents that cited each reason.

Restriction	Most common motivation	2nd most common motivation
Access/transportation	Landowner objectives (57%)	Professional judgment (56%)
Annosum root rot	Professional judgment (48%)	Landowner objectives (37%)
Biomass harvesting guidelines	Forest certification (37%)	Professional judgment (35%)
Cultural or archaeological	Program requirements (e.g. MFL) (62%)	Forest certification (45%)
Invasive species	Professional judgment (55%)	Program requirements (e.g. MFL) (46%)
Oak wilt	Professional judgment (67%)	Program requirements (e.g. MFL) (54%)
Pest restrictions	Professional judgment (52%)	Landowner objectives (34%)
Rare species	State endangered species regulations (75%)	Federal Endangered Species Act regulations (68%)
Recreation	Landowner objectives (81%)	Professional judgment (15%)
Soil disturbance	Professional judgment (78%)	Forest certification (62%)

Responses to restrictions

When timber availability fluctuates seasonally as has been demonstrated, procurement managers must make adjustments to ensure their mill is supplied with wood throughout the year. Therefore, it is not surprising that 70% of responding mills had adjusted their procurement practices as a result of seasonal timber harvesting restrictions. This included 100% of responding pulpmills, 66% of medium and large sawmills, and 63% of small sawmills.

Mills made a variety of changes to their procurement practices. Fifty percent of responding mills reported altering their species mix as a result of seasonal timber harvesting restrictions. Fifty-five percent of medium and large sawmills, 53% of small sawmills, and 33% of pulpmills had altered their species mix. Other common changes included increased delivered prices, increased inventory levels, and increased use of satellite wood yards (Table 4). As is the case for most responses to seasonal restrictions, there was significant variation in the response to the seasonal restrictions. In general, a greater percentage of pulpmills reported changes in procurement practices than sawmills.

Peak inventory levels exceeded 30 days for each quarter of the year for each mill type (Figure 3). Peak inventory levels were highest during the first quarter, declined in the second quarter, and were lowest during the third and fourth quarters. During the first quarter, mills generally build inventory while logging conditions are at their best. Inventories generally decline during the second quarter as very little wood is delivered to most mills because reduced road weight limits associated with spring break-up restrict timber deliveries during the early second quarter and access and oak wilt restrictions limit timber availability during the latter part of the quarter. During the third and fourth quarters, mills can hold lower inventories because more timber is available (Table 1) and public roads can support truck traffic. A similar pattern was reported by many pulpmills in Maine where spring thaw is also an issue (Todd and Rice 2005).

Responding mills reported the number of days of inventory currently held in each quarter and the number of days of inventory that would be necessary absent seasonal harvesting restrictions. Respondents reported relatively high inventory levels, particularly during the first and second quarters (Figure 3). However, inventory strategies relative to seasonal restrictions were highly variable, and therefore the only statistically significant differences in inventory levels brought about by seasonal restrictions were increases in inventory levels in the first quarter for both pulpmills and small sawmills, and in the second quarter for small sawmills.

Seasonal timber harvesting restrictions was the most important factor that influenced inventory levels for pulpmills, while weather was the most important factor for sawmills of all sizes. Timber availability and weather were both rated as important factors in determining inventory levels for mills of all types (i.e. mean response $\geq$ 4 on 5-point Likert scale)

Deterioration in timber quality during storage is of significant concern for mills. Samistraro and Hart (2012) found that for a 1,000 ton per day mill, using wood that had been stored for 11 weeks would cost the mill approximately $50,000 per day more than if they used freshly cut wood because of moisture loss during storage. Quillin (1994) estimated that chip inventory increases the cost of producing kraft pulp by $2 per bone dry ton for each 30 days of storage. He estimated that over the course of a year chip deterioration could cost a 1,000 ton per day mill $720,000. Chip piles generally deteriorate because of biological/biochemical reactions and physical damage or contamination.

Table 4: Changes in procurement practices resulting from seasonal timber harvesting restrictions by mill type.

Practice	Mill type[1]	Percent of respondents		
		Increased	No change	Decreased
Purchases from dealers/brokers	Medium and large sawmill	11	78	11
	Small sawmill	25	68	7
	Pulpmill	44	56	0
Direct stumpage purchases	Medium and large sawmill	10	80	10
	Small sawmill	38	50	12
	Pulpmill	22	67	11
Gatewood purchases from loggers	Medium and large sawmill	30	40	30
	Small sawmill	36	57	7
	Pulpmill	33	33	33
Long term wood supply agreements	Medium and large sawmill	20	70	10
	Small sawmill	19	69	12
	Pulpmill	44	56	0
Inventory level	Medium and large sawmill	20	50	30
	Small sawmill	42	35	23
	Pulpmill	89	0	11
Satellite wood yards	Medium and large sawmill	40	50	10
	Small sawmill	8	92	0
	Pulpmill	89	11	0
Procurement staff	Medium and large sawmill	20	80	0
	Small sawmill	12	88	0
	Pulpmill	44	56	0
Delivered price	Medium and large sawmill	70	30	0
	Small sawmill	46	54	0
	Pulpmill	89	11	0
Mill production while restrictions are in place	Medium and large sawmill	0	70	30
	Small sawmill	7	52	41
	Pulpmill	0	89	11

[1]Medium and large sawmill = 50,000+tons; Small sawmill = <50,000 tons

The cost to sawmills of value losses due to long term storage are highly variable depending on variables such as lumber grade and species. Value losses may result from end checking of logs, insect attacks, and sapwood stains (Simpson and Ward 1991). The risk of end checking is increased during warm weather (Linares-Hernandez and Wengert 1997), which is the time of year we found to have the greatest percentage of sales restricted (Table 1). Log costs may account for up to 80% of operating costs from hardwood sawmills, and therefore value losses resulting from extended storage may have a substantial impact on sawmill profits. Linares-Hernandez and Wengert (1997) found that after twelve weeks of storage hard maple (*Acer spp.*) logs had blue stain on an average of 13 inches of each log. Likewise hard maple logs experienced end splits averaging 4 inches while red oak logs experienced splits averaging 6 inches. Linares-Hernandez and Wengert (1997) found that stains and splits could be reduced substantially by end coating logs with a wax emulsion.

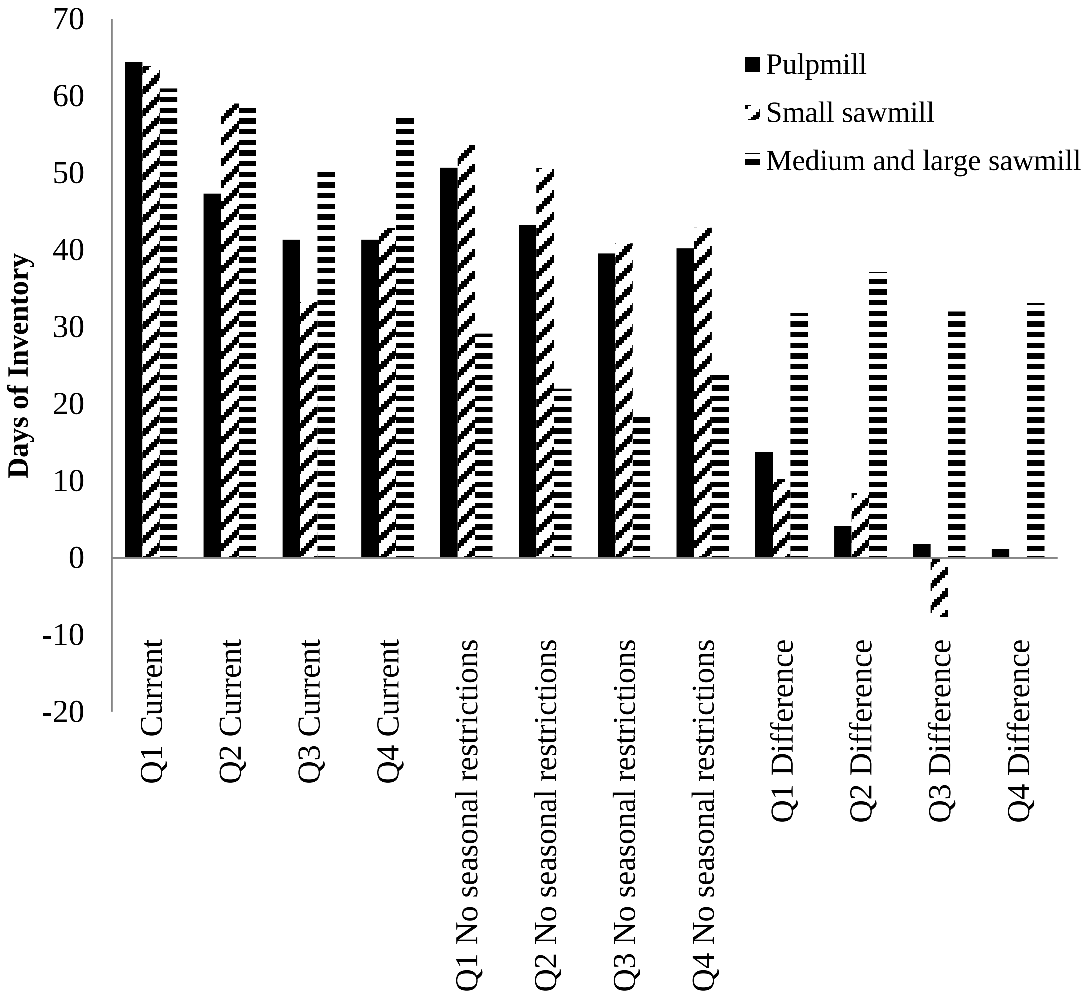

Figure 3: Peak quarterly inventory currently, if seasonal timber harvesting restrictions did not exist, and the difference between current quarterly inventory levels and what would be necessary absent seasonal restrictions. Quarterly inventory levels refer to peak levels of inventory each quarter.

Costs of seasonal restrictions in Wisconsin

Reductions in stumpage prices

Each restriction listed was reported to reduce stumpage prices when applied and there were no significant differences between groups of foresters (Figure 4). Requiring that aspen stands be harvested during the winter resulted in the greatest reduction in stumpage prices (12.5% reduction). Cultural/archaeological restrictions caused the smallest reduction in stumpage prices (3.9%).

Based on the frequency of seasonal restrictions found in this study and foresters' estimates of stumpage price reductions, we estimate that the cumulative loss resulting from stumpage price reductions is $22.2 million per year (Table 5). While this is a large number, it accounts for $3.15 per ton on average for sales with at least one seasonal restriction. To put this in context, a forty acre timber sale that removed 30 tons per acre would yield $3,780 less if a seasonal restriction was applied. Obviously, this will vary significantly from sale to sale, and the application of a seasonal restriction is not the only factor that influences stumpage prices. Nonetheless, this study demonstrates the potential for significant costs to landowners when seasonal restrictions are applied.

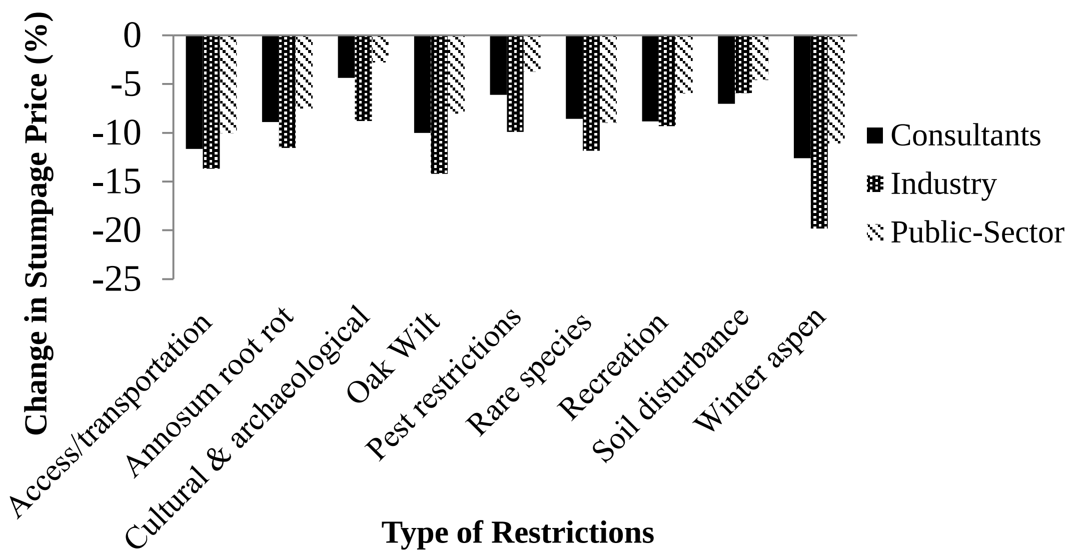

Figure 4: Average change in stumpage price as a result of each seasonal restriction as reported by Wisconsin foresters.

Table 5: Estimated reduction in stumpage prices resulting from seasonal timber harvesting restrictions estimated from stumpage prices from Prentiss and Carlyle (2015), stumpage price reductions reported by foresters, and harvest volume by species from the WDNR (2015d).

Species	Tons harvested per year (2009-2012)	Estimated percent of sales restricted	Reported percent reduction in stumpage price	Weighted average stumpage price ($/ton)	Estimated Landowner Cost ($)
Aspen	1,959,173	67	12.6	26.08	4,313,340
Hard maple	1,444,608	67	10.8	39.49	4,128,122
N. red oak	773,490	100	9.5	47.64	3,058,351
Red pine	1,042,038	100	8.3	33.58	2,904,690
Soft maple	882,263	67	10.8	21.90	1,398,316
Red oak	267,843	100	9.5	45.90	1,167,993
Basswood	394,107	67	10.8	15.51	442,188
White pine	288,965	100	8.3	22.67	543,687
Jack pine	398,710	100	8.3	22.58	747,355
White birch	423,600	67	10.8	23.24	712,262
Other hardwoods	235,481	67	10.8	32.77	558,430
Ash	367,558	67	10.8	25.19	669,993
Balsam fir	157,931	67	8.3	15.88	139,488
White oak	199,913	100	9.5	52.05	988,459
Other softwoods	199,990	67	10.8	26.26	379,965
				Total cost	22,152,639
				Cost per ton	3.15

Wisconsin foresters perceived that the overall health of Wisconsin timber markets was the most important factor influencing stumpage prices (Table 6). The proximity to mills was the second most highly rated factor. Seasonal timber harvesting restrictions applied to the sale were the third most highly rated influence on stumpage prices according to industry foresters, but just the seventh most important factor according to consulting foresters and public agency foresters. The reasons for this perceived difference are unclear. It is possible that consultants and public sector foresters do not fully understand the impact that seasonal restrictions have on stumpage prices. On the other hand, industry foresters may have overestimated the impact of seasonal restrictions on stumpage prices because of the other impacts of seasonal restrictions on their company. Nevertheless, each group rated seasonal timber harvesting restrictions as an important influence on stumpage prices. These results underscore the importance of all timber sale characteristics in determining likely stumpage prices. Seasonal restrictions may not be the most important characteristic in determining stumpage prices, but the inclusion of these restrictions was predicted to reduce stumpage prices by, in some cases, 10% or more (Figure 4).

Consultants, industry foresters, and public sector foresters reported that over the past five years, an average of 2.3, 4.1, and 1.1 sales, respectively, failed to sell annually because of seasonal restrictions. The percentage of sales that failed to sell each year varied from 4% of sales offered by consultants to 1.3% of sales offered by public sector foresters and this difference was significant. Nonetheless, more than half of industry and public sector foresters did not report a failed sale as a result of seasonal restrictions within the past five years.

Table 6: Perceived importance of factors on stumpage prices by consulting foresters, industry foresters, and public sector foresters. Foresters were asked to rate the importance of each characteristic on a 5 point scale (1 = not important, 3 = moderately important, 5 = very important).

	Mean Response		
Factor	Consultants	Industry	Public sector
Health of Wisconsin timber markets	4.72^{A}	4.61^{A}	4.60^{A}
Proximity of sale to mills	4.31^{A}	4.61^{A}	4.24^{A}
Competition between loggers	4.26^{A}	3.74^{A}	4.08^{A}
Species of timber	4.28^{A}	4.22^{A}	4.08^{A}
Size of timber sale	4.16^{A}	4.13^{A}	3.96^{A}
Health of the US economy	4.15^{A}	3.74^{A}	3.90^{A}
Seasonal restrictions	3.85^{A}	4.57^{B}	3.66^{A}
Government regulations	3.74^{A}	4.22^{A}	3.29^{B}
Silvicultural prescription	3.28^{A}	3.83^{A}	3.22^{A}

^{A,B}Numbers in rows connected by the same letter are not significantly different (α =0.05).

Impact on foresters

Seasonal restrictions not only affect the stumpage prices that landowners receive, they have the potential to negatively impact foresters and the organizations that employ them. All three groups of foresters agreed that each seasonal restriction listed had a negative impact on their organization (Table 7). Recreation-related restrictions had the largest negative impact on consulting firms, while oak wilt restrictions had the largest impact on industry, and rare species restrictions had the most negative impact on public agencies.

These findings are somewhat surprising, as foresters' professional judgment was one of the top two motivating factors for requiring most of the seasonal restrictions (Table 3). This suggests that foresters believe that most of these restrictions are necessary to protect the resource, and are willing to require them in timber sales even though the restrictions negatively impact their organization.

Table 7: Perceived impact of seasonal timber harvesting restrictions on foresters' organizations. Foresters were asked to rate the impact of each restriction on their organization (1 = large negative impact, 3 = no impact, 5 = large positive impact).

Restriction	Forester Type	% Positive impact	% Negative impact	Mean response
Access/transportation	Consultants	9	65	2.37*A
	Industry	4	91	1.79*B
	Public sector	8	49	2.54*A
Annosum root rot	Consultants	9	47	2.63*A
	Industry	4	61	2.38*A
	Public sector	16	40	2.82*A
Cultural or archaeological	Consultants	5	33	2.67*A
	Industry	0	78	2.13*B
	Public sector	12	36	2.77*A
Oak wilt	Consultants	11	56	2.47*A
	Industry	0	96	1.46*B
	Public sector	16	50	2.73*A
Pest restrictions	Consultants	4	40	2.62*A
	Industry	0	83	1.92*B
	Public sector	12	36	2.81*A
Rare species	Consultants	4	54	2.37*A
	Industry	0	96	1.63*B
	Public sector	12	56	2.49*A
Recreation	Consultants	4	70	2.23*A
	Industry	0	83	1.96*A
	Public sector	8	41	2.66*A
Soil disturbance	Consultants	5	49	2.58*A
	Industry	9	61	2.42*A
	Public sector	18	47	2.79*A

*Response was significantly different from no impact ($\alpha = 0.05$).
A,B,Numbers in rows connected by the same letter are not significantly different ($\alpha = 0.05$).

Costs to Wisconsin mills

The largest cost of seasonal timber harvesting restrictions for pulpmills and small sawmills resulted from increased inventory requirements (Table 8). For pulpmills, increased inventories cost each firm an average of over $1.5 million, or $3.55 per ton of delivered wood. For small sawmills, the average per firm cost was $85,000, and $5.59 per ton. The cost of satellite wood yards cost pulpmills an average of $706,250, or $1.11 per ton. This is consistent with past estimates that timber delivered from satellite wood yards can cost $10 per ton more than timber delivered directly from the woods (Martin 2001 as cited in Gallagher et al. 2008). For small sawmills the second largest cost incurred from seasonal restrictions was reduced wood quality resulting from extended storage, which cost $50,526, or $5.46 per ton. In total, pulpmills estimated that seasonal restrictions cost an average of $2.6 million per firm ($4.90 per ton) and small sawmills reported an average cost of $193,683 per firm ($16.49 per ton).

Table 8: Mean cost of seasonal timber harvesting restrictions with standard errors (in parentheses) to forest products industry mills in Wisconsin. Only four medium and large sawmill responded to this question, and so caution should be applied when interpreting these values. The mean cost per ton was calculated by dividing the cost reported by the number of tons of wood purchased annually by the responding firm.

Type of cost	Mill type[1]	Mean cost per firm ($)	Mean cost per ton ($)	% Respondents Reporting Cost
Down-time or reduced production	Medium and large sawmill	$25,000 ($21,862)	$0.25 ($0.22)	25
	Small sawmill	$47,105 ($17,084)	$3.75 ($2.31)	53
	Pulpmill	$0 ($0)	$0 ($0)	0
Increased inventory	Medium and large sawmill	$25,000 ($21,862)	$0.06 ($0.05)	25
	Small sawmill	$85,000 ($48,892)	$5.59 ($3.38)	42
	Pulpmill	$1,671,250 ($523,946)	$3.55 ($1.54)	100
Reduced wood quality from extended storage periods	Medium and large sawmill	$25,000 ($21,862)	$0.25 ($0.22)	25
	Small sawmill	$50,526 ($38,678)	$5.46 ($2.90)	47
	Pulpmill	$111,875 ($43,243)	$0.13 ($0.05)	50
Satellite wood yards and increased transportation costs	Medium and large sawmill	$62,500 ($54,655)	$0.16 ($0.14)	25
	Small sawmill	$8,947 ($5,283)	$0.25 ($0.14)	21
	Pulpmill	$706,250 ($239,148)	$1.11 ($0.35)	75
Personnel costs	Medium and large sawmill	$0 ($0)	$0 ($0)	0
	Small sawmill	$2,105 ($1,945)	$1.44 ($1.33)	5
	Pulpmill	$12,500 ($8,539)	$0.02 ($0.01)	13
Other costs	Medium and large sawmill	$0 ($0)	$0 ($0)	0
	Small sawmill	$0 ($0)	$0 ($0)	0
	Pulpmill	$150,000 ($102,470)	$0.09 ($0.06)	13
Total costs per firm	Medium and large sawmill	$137,500	$0.72	
	Small sawmill	$193,683	$16.49	
	Pulpmill	$2,651,875	$4.90	

[1]Medium and large sawmill = 50,000+tons; Small sawmill = <50,000 tons

Gibeault and Coutu (2014) found that the average delivered cost of hardwood pulpwood was \$6.78 per ton higher in the Lake States compared to the U.S. South. Gibeault and Coutu (2014) suggested that much of this difference could be attributed to high inventory levels and wood transfers resulting from seasonal supply constraints, as well as shortwood handling costs. Our study supports the conclusion that seasonal restrictions impose a significant cost on Wisconsin's forest industry. If the cost of seasonal restrictions estimated in this study were subtracted from the delivered prices reported by Gibeault and Coutu (2014), Wisconsin's hardwood pulpwood would be cost-competitive with every region, conifer pulpwood would be competitive with every region except for the U.S. South, and the state would further increase its advantage in aspen pulpwood.

Small sawmills reported the greatest per-ton costs incurred because of seasonal restrictions. This could be explained by the narrow range of product specifications and the higher delivered price paid for raw material. For example, a sawmill that purchased primarily oak would be affected by oak wilt restrictions much more than a pulpmill that relies on a mix of species. In addition, because raw material costs account for up to 80% of operating costs (Linares-Hernandez and Wengert 1997), they may be more susceptible to financial losses from reductions in log quality resulting from extended storage, such as staining. Indeed, this was the largest seasonal restrictions cost component for small sawmills (Table 8). Likewise, the requirement to store timber for long periods could represent a greater financial burden for small sawmills than for larger organizations, especially if the need for long-term storage would be unnecessary absent seasonal restrictions.

Relative impact of specific restrictions on Wisconsin mills

Respondents rated access/transportation, oak wilt, and seasonal weight limits as having the greatest negative impact on their firm (Table 9). The mean response to each restriction was less than three, meaning that respondents perceived that each restriction had a negative impact on their firm. This makes sense because any factor that reduces the availability of timber to a mill would be expected to impact that mill negatively. However, those restrictions that impact large acreages or impact a large portion of the year would be expected to affect mills most.

Pulpmills rated oak wilt restrictions as the most burdensome type of seasonal restriction (Table 9). Oak/hickory is the most common forest type in Wisconsin, especially in the parcel sizes that are most likely to be harvested (Perry 2015). Guidelines in place at the time of the survey recommended avoiding harvesting timber in stands with $\geq 15\ ft^2\ ac^{-1}$ of oak basal area between early to mid-April and July 15th, meaning that oak wilt restrictions cover a large area and restrict harvesting for one-quarter of the year. For mills that require oak for their operations, this means increasing inventory substantially before the restrictions go into effect.Annosum root rot restrictions were considered to have smaller impacts than other restrictions (Table 9). There are several potential reasons for this. First, because conifers cover fewer acres in Wisconsin, many mills do not utilize them and the overall impact would be lower than for oak wilt and seasonal weight limits. Perhaps most importantly, however, annosum root rot restrictions generally require stump treatments during most of the year rather than prohibiting the harvest of conifers during portions of the year as oak wilt restrictions do. Therefore, while costs are incurred to treat stumps, and some of this cost may be passed from loggers to mills, these costs are much lower than for restrictions that reduce the supply of timber for long periods. Stump treatment allows loggers to "opt out" of a harvest restriction by the addition of money, in the form of stump treatment. This is a preferred option, because it allows loggers/mills to adjust their inventory of potential sales to meet their needs more efficiently.

Table 9: Mean rating (with standard errors) of nine seasonal restrictions on Wisconsin mills (1 = large negative impact, 5 = large positive impact) and the percentage of respondents reporting positive and negative impacts from each restriction.

Restriction	Mill type[1]	% Positive	% Negative	Mean response
Oak wilt				
	Medium and large sawmill	0	78	1.67*(0.20)
	Small sawmill	23	57	2.47* (0.24)
	Pulpmill	11	89	1.67* (0.21)
Seasonal weight limits	Medium and large sawmill	0	82	1.64* (0.15)
	Small sawmill	17	73	2.23* (0.21)
	Pulpmill	11	89	1.89* (0.27)
Access/transportation	Medium and large sawmill	0	80	2.00* (0.14)
	Small sawmill	17	69	2.24* (0.23)
	Pulpmill	1	89	1.78* (0.27)
Soil/hydrological disturbance	Medium and large sawmill	0	50	2.40* (0.14)
	Small sawmill	20	60	2.50* (0.18)
	Pulpmill	11	78	2.00* (0.21)
Recreation restrictions	Medium and large sawmill	0	40	2.60* (0.11)
	Small sawmill	17	50	2.63* (0.15)
	Pulpmill	11	89	2.00* (0.18)
Rare species/wildlife	Medium and large sawmill	0	30	2.60* (0.14)
	Small sawmill	17	40	2.70 (0.15)
	Pulpmill	11	78	1.89* (0.29)
Pest restrictions (e.g. invasive species)	Medium and large sawmill	0	60	2.20* (0.16)
	Small sawmill	17	53	2.57* (0.17)
	Pulpmill	11	89	2.11* (0.17)
Cultural/archaeological	Medium and large sawmill	0	20	2.80* (0.09)
	Small sawmill	10	27	2.90 (0.12)
	Pulpmill	11	67	2.11* (0.17)
Annosum root rot	Medium and large sawmill	0	33	2.67* (0.11)
	Small sawmill	7	27	2.80 (0.11)
	Pulpmill	0	44	2.33* (0.18)

[1]Medium and large sawmill = 50,000+tons; Small sawmill = <50,000 tons
*Mean responses are significantly different from no impact ($\bar{x}$ = 3) (α = 0.05).

Respondents reported, on average, that each seasonal restriction increased delivered prices between 0 and 10% (Figure 5). These values were highly variable, with a median response of zero for each restriction. Seasonal weight restrictions had the greatest impact on delivered prices, perhaps because this restriction affects all species and all mills within the state. For the other restrictions, they do not affect all species and are generally applied to individual sites, meaning that they often do not directly impact delivered prices. These restrictions are likely to increase delivered prices indirectly by reducing timber supply during a portion of the year. The major costs for mills appear to be associated with increased inventory levels and associated reductions in timber quality resulting from extended storage rather than increased delivered prices (Table 8).

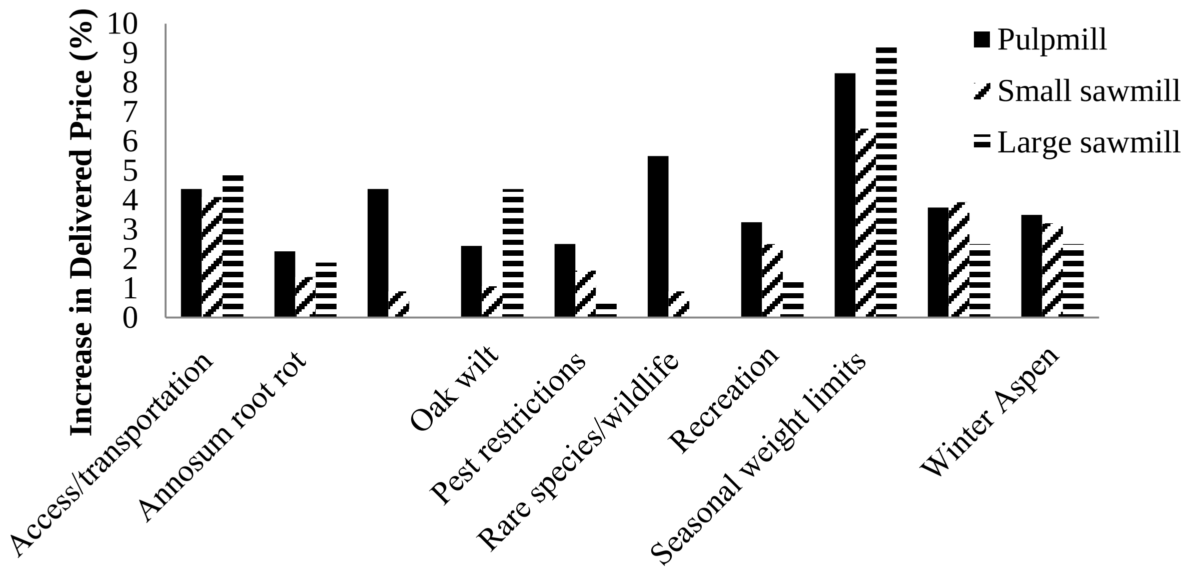

Figure 5: Percent increase in delivered prices resulting from seasonal restrictions when those restrictions are in place.

Respondents were asked their opinions of seasonal timber harvesting restrictions as they are currently applied. The qualifier, "as currently applied," was added to the questions after pre-testing because several individuals pointed out that forest industry personnel recognize the need for some seasonal restrictions, but suggested that restrictions are applied in instances when they are not necessary, which increases costs for industry, but does little to protect the resource. Therefore, these responses should not be considered support or opposition to seasonal restrictions generally. Rather, they reflect perceptions of how seasonal timber harvesting restrictions are currently applied.

Pulpmills and medium and large sawmills disagreed with the notion that seasonal restrictions are a cost-effective method of protecting the environment, while the response from small sawmills was not statistically different from neutral (Table 10). All three mill types agreed that seasonal restrictions had increased the cost of delivered wood. As was demonstrated previously, most of this cost increase appears to result from increased inventory levels and associated declines in wood quality resulting from extended storage rather than a direct increase in prices paid to loggers for delivered wood, although that has happened as well (Table 8, Figure 5). Eighty-nine percent of pulpmills suggested that seasonal restrictions make Wisconsin's forest industry less competitive in the marketplace.

Table 10: Forest industry representatives' views of seasonal timber harvesting restrictions as currently applied.

Seasonal timber harvesting restrictions, as currently applied are or have:	Mill type[1]	% Agree	% Disagree	Mean response (1 = strongly disagree, 5 = strongly agree)
A cost-effective method of protecting the environment.	Medium and large sawmill	0	50	2.30*AB (0.17)
	Small sawmill	29	42	2.74A (0.19)
	Pulpmill	0	89	1.67*B (0.15)
Increased the cost of delivered wood to this mill.	Medium and large sawmill	50	20	3.60*A (0.24)
	Small sawmill	69	13	3.66*A (0.17)
	Pulpmill	100	0	4.78*B (0.09)
Common on timber sales on private land in Wisconsin.	Medium and large sawmill	20	10	3.20A (0.16)
	Small sawmill	63	22	3.47*A (0.20)
	Pulpmill	78	0	4.11*A (0.17)
Common on timber sales on county and state forestland in Wisconsin.	Medium and large sawmill	50	20	3.30A (0.17)
	Small sawmill	72	3	4.09*AB (0.15)
	Pulpmill	100	0	4.78*B (0.09)
Benefit Wisconsin's forest industry.	Medium and large sawmill	0	50	2.40*A (0.14)
	Small sawmill	25	50	2.66A (0.18)
	Pulpmill	0	78	1.89*A (0.17)
Benefit Wisconsin' forest landowners.	Medium and large sawmill	10	30	2.70A (0.17)
	Small sawmill	32	39	2.90A (0.17)
	Pulpmill	11	67	2.44A (0.15)
Benefit the health of Wisconsin's forests.	Medium and large sawmill	0	33	2.56*A (0.17)
	Small sawmill	41	28	3.19A (0.17)
	Pulpmill	11	67	2.33*A (0.18)
Benefit wildlife and increase the environmental services provided by forests.	Medium and large sawmill	0	50	2.40*A (0.14)
	Small sawmill	19	34	2.75A (0.14)
	Pulpmill	0	67	2.11*A (0.17)
Make Wisconsin's forest industry less competitive in the marketplace.	Medium and large sawmill	40	10	3.50*AB (0.20)
	Small sawmill	47	19	3.44*A (0.17)
	Pulpmill	89	0	4.56*B (0.15)

[1]Medium and large sawmill = 50,000+tons; Small sawmill = <50,000 tons

*Mean response was statistically different from neutral ($\bar{x}$ = 3, α =0.05).

ANote: Responses connected by the same letter are not statistically different using the Kruskal-Wallis test (α = 0.05).

Pulpmills and medium and large sawmills disagreed with the statement that seasonal restrictions benefit Wisconsin's forest industry, while the response from small sawmills was not statistically different from neutral (Table 10). More respondents disagreed than agreed with the idea that the restrictions benefit Wisconsin landowners, although the mean response was not different from neutral.

Annosum root rot stump treatment cost estimate

Since 2013, the state of Wisconsin has required that pine stumps be treated with Cellu-Treat or Sporax between April 1st and November 30th on state timber sales, and recommends the practice on other sales (WDNR 2013). This requirement affects the wood supply chain differently than restrictions associated with oak wilt prevention, access, and soil/hydrology concerns because stump treatment does not restrict harvesting during any part of the year as long as the stumps are treated. Nonetheless, when stump treatment is required, this imposes a cost on loggers and timber buyers.

The logging businesses that we contacted estimated that it costs between $3,500 and $15,000 to equip a harvester to treat stumps to prevent annosum root rot, depending on the make and model of equipment and who installs the treatment apparatus (Table 11). In addition, Cellu-Treat generally costs approximately $3 per pound. Loggers estimated that the cost of chemical application alone costs between $5.60 and $18 per acre. Using the average volume per acre from 2014 county timber sales that were at least 75% softwood, we estimate that Cellu-treat chemical costs between $0.16 and $0.50 per ton. Of course, these costs will vary considerably depending on application rates, tree size, and other factors. In our conversations, loggers emphasized the time and cost associated with obtaining a pesticide applicators license. In order to obtain this license, an operator should spend approximately two weeks studying, travel and exam time requires a full day (which means that one day of production is lost), and there is a relatively high failure rate, meaning that more time and money is lost if the operator must retake the test.

Overall, we estimate that applying Cellu-Treat to stumps can cost loggers between $0.31 and $2.18 per ton of timber harvested, and can cost significantly more if the logger harvests a small volume of pine annually (Table 12). Because of the high fixed costs associated with equipping a harvester to apply the chemical, loggers that harvest a small volume of pine annually can incur very high costs on a per-ton basis, whereas loggers that harvest a large volume of pine annually incur relatively low per-ton costs, much of which is associated with purchasing the chemical itself. Of course, those loggers that harvest small volumes of softwood annually can elect to treat stumps using a hand or backpack sprayer; however, this requires a licensed applicator to walk the site after the harvester processes the trees. This means that an additional person is needed on the site, or the equipment operator must shut down the machine to treat the stumps, resulting in costly production losses. Treating stumps using a hand or backpack sprayer is estimated to cost under $10 per acre (Scanlon 2008); however, this cost does not include the opportunity cost of lost production while stumps are being treated.

Table 11: Cost estimates to equip and maintain a harvester to treat stumps with Cellu-Treat to prevent annosum root rot.

Cost component	Cost	Longevity/frequency	Notes
Sprayer attachment and components	$3,000-$15,000	Life of machine	Varies depending on machine make and model and who installs treatment system
Maintenance/repair costs	$500-$600/yr	Annual	
Perforated saw bars	$125-$450	Same as typical bar	Cost is 3-4 times the cost of typical bar
Pesticide applicator license	$500-$700	Initial exam + $51.20 annual renewal	20 hours study time, 1 day for review and exam, travel cost to testing site, one day of lost production; assumes the exam is passed on the first try
Cellu-treat chemical	$3.00-$3.60/pound of chemical; $5.60-$18/acre; estimated $0.16-$0.50/ton	1 pound makes 2 gallons of liquid	Cost per ton is highly variable depending on application rate, amount of overspray, tree size, etc.

Table 12: Per-ton cost estimates based on production from four logging businesses provided as part of the Wisconsin Forest Practices Study and component costs provided in Table 11.

Logging crew description	Loads per week	% Softwood	Softwood harvested (tons/yr)	Fixed costs ($/yr)	Variable costs ($/ton)	Range of treatment costs ($/ton)
High production, low softwood %	16.3	13.1	2,750	1,610-4,618	0.16-0.50	0.75-2.18
High production, high softwood %	17.1	34.7	7,643	1,610-4,618	0.16-0.50	0.37-1.10
Low production, low softwood %	11.6	1.5	224	1,610-4,618	0.16-0.50	7.35-21.11
Low production, high softwood %	9.5	87	10,645	1,610-4,618	0.16-0.50	0.31-0.93

While the cost of treating stumps to prevent annosum root rot may not have as large an impact on the wood supply chain as restrictions associated with oak wilt and protecting wet soils (Tables 7 and 9), this requirement does impose costs on loggers and timber buyers, which may then be passed along to forest landowners and mills. Furthermore, because of the low availability of timber between mid-March and July (Table 1), loggers that harvest hardwoods for much of the year may be compelled to equip their harvesters to treat stumps so that they can harvest pine stands during the spring and early summer months when many hardwood stands are off-limits. However, outfitting equipment to harvest a small volume of pine each year can lead to high per-ton costs because fixed costs are spread over a relatively small volume (Table 12).

Potential impact of seasonal timber availability on logging business profitability

Seasonal variation in timber availability can have significant ramifications for logging businesses. Most timber in Wisconsin is harvested by mechanized loggers that may have $1 million or more invested in equipment (Rickenbach et al. 2015). With high fixed costs, consistent production throughout the year is a necessity. However, previous research indicates significant seasonal variation in logging productivity (Conrad et al. 2015).

The Wisconsin Forest Practices Study (Prisley et al. 2014-2015) found that loggers were most productive during winter. Logging efficiency was similar in fall and winter, but lower during spring and summer (Table 13). For this study, efficiency was measured using stochastic frontier analysis, which calculated efficiency based on production data and the labor and capital required to achieve that production level. The analysis was based on production data provided by 30 logging crews between fall of 2014 and summer of 2015.

This data suggests that a hypothetical logger generating $20 per ton of revenue would lose approximately $10,500 over the course of a year (Table 13). The logger would generate a profit during fall and winter, but would suffer losses during spring and summer. We assumed that the logger shuttered operations for six weeks while spring break-up weight limits were in effect, which is consistent with observations from the Wisconsin Forest Practices study. The losses incurred during spring and summer were a result of fewer hours worked and lower efficiency when the crew was working.

If the hypothetical logger maintained the same level of efficiency during spring and summer as during fall and winter, profit would be approximately $8,333 (Table 14). This represents a difference of nearly $20,000 relative to the previous example. While seasonal variation in efficiency cannot be fully assigned to seasonal restrictions, the large percentage of timber sales unavailable in spring and summer may have forced loggers to operate on small parcels or otherwise difficult tracts that reduced efficiency. Nonetheless, if efficiency were improved, as a result of fewer seasonal timber harvesting restrictions or other changes, it could make a significant difference in loggers' bottom lines.

In the final scenario, under the extreme example of seasonal restrictions that prohibited timber harvesting between mid-March and August 1st, the hypothetical logger would suffer a loss of over $80,000 (Table 15). This represents differences of approximately $70,000 compared to the present scenario and nearly $90,000 compared to a situation with greater efficiency.

Table 13: Projected profit for a cut-to-length logging crew that generates $20 per ton of revenue and is subject to current seasonal variation in timber availability. Productivity and efficiency data was collected as part of the Wisconsin Forest Practices Study while costs were estimated using the machine rate method.

Season	Weeks per season	Loads per week	Efficiency (%)	Hours worked per week	Fixed cost per season ($)	Variable and labor costs ($)	Total cost ($)	Total Revenue ($)	Profit ($)
Fall	13	11.7	73.3	37.2	43,250	40,851	84,101	88,218	4,117
Winter	13	15.6	73.2	43.4	43,250	47,640	90,890	117,624	26,734
Spring	7	7.8	61.6	33.9	43,250	20,030	63,280	31,668	-31,612
Summer	13	9.5	62.3	34.7	43,250	38,109	81,359	71,630	-9,729
								Total profit	-10,490

Table 14: Projected profit for a cut-to-length logging crew that generates $20 per ton of revenue and is able to maintain consistent efficiency between seasons. Productivity and efficiency data was collected as part of the Wisconsin Forest Practices Study while costs were estimated using the machine rate method.

Season	Weeks per season	Loads per week	Efficiency (%)	Hours worked per week	Fixed cost per season ($)	Variable and labor costs ($)	Total cost ($)	Total Revenue ($)	Profit ($)
Fall	13	11.7	73.3	37.2	43,250	40,851	84,101	88,218	4,117
Winter	13	15.6	73.3	43.4	43,250	47,640	90,890	117,785	26,894
Spring	7	9.3	73.3	33.9	43,250	20,030	63,280	37,683	-25,597
Summer	13	11.2	73.3	34.7	43,250	38,109	81,359	84,277	2,918
								Total profit	8,333

Table 15: Projected profit for a cut-to-length logging crew that generates $20 per ton of revenue, maintains current levels of efficiency between seasons, but is prohibited from harvesting timber between mid-March and August 1st. Productivity and efficiency data was collected as part of the Wisconsin Forest Practices Study while costs were estimated using the machine rate method.

Season	Weeks per season	Loads per week	Efficiency (%)	Hours worked per week	Fixed cost per season ($)	Variable and labor cost per season ($)	Total cost ($)	Total Revenue ($)	Profit ($)
Fall	13	11.7	73.3	37.2	43,250	40,851	84,101	88,218	4,117
Winter	13	15.6	73.2	43.4	43,250	47,640	90,890	117,624	26,734
Spring	0	0	0	0.0	43,250	0	43,250	0	-63,280
Summer	6	9.5	62.3	34.7	43,250	17,589	60,839	33,060	-48,299
								Total profit	-80,728

As these three scenarios demonstrate, the seasonal availability of timber can have a significant impact on loggers' finances (Tables 13-15). Fully mechanized loggers have high fixed costs, and therefore they must be able to harvest timber throughout the year in order to remain profitable. It should be noted again that the costs and revenues provided above are hypothetical and do not represent those of an individual logger. Loggers' costs and revenues will vary considerably depending on the equipment used and site characteristics. For example, many loggers operate equipment that is ten or more years old; these loggers would incur fixed costs that are much lower than those assumed here, but presumably would have higher variable costs for maintenance and repair. The machine rate method is designed to give an average cost of owning and operating logging equipment over the life of each machine, but actual costs will certainly be different from those presented here.

Predictors of winning bid value on Wisconsin County Forest timber sales 2014

Of the 660 timber sale prospectuses and bid results that we analyzed for Wisconsin County Forest timber sales during 2014, 67% had at least one seasonal timber harvesting restriction. This is consistent with results for sales that closed in 2013 (Table 2). Thirty-four percent of the sales were restricted to winter harvesting or frozen ground and 33% had some other restriction. Twenty percent of sales had oak wilt restrictions and 16% of sales required stump treatment to prevent annosum root rot.

The multiple linear regression model explained approximately 68.6% of the variation in bid values (Table 16). All of the included variables were statistically significant at the 1% level. Requiring that a timber sale be harvested during winter or when the ground was frozen was a significant predictor and this requirement was associated with a reduction in the winning bid price of $141. This finding is consistent with results of the forester survey (Figure 4) and a similar analysis conducted in Minnesota (Barron et al. 2015).

Table 16: Results from the multiple linear regression model with the dependent variable the winning bid value per acre for timber sales sold from the Wisconsin County Forests in 2014.

Independent variables	Coefficient	Standard error	95% Confidence Interval		P-value
			Lower bound	Upper bound	
Intercept	109.65	35.09	40.72	178.58	0.002
Tons per acre	24.59	0.76	23.10	26.08	<0.001
Aspen %	-2.48	0.49	-3.45	-1.51	<0.001
Hardwood %	-1.78	0.35	-2.46	-1.10	<0.001
Winter only/frozen ground	-141.34	23.71	-187.91	-94.77	<0.001
Quarter 1	-146.41	45.03	-234.85	-57.97	0.001
Quarter 4	85.43	22.82	40.61	130.25	<0.001
Model fit:					
R^2 = 0.689					
Adjusted R^2 = 0.686					
F-statistic = 207.80 (p<0.001)					

The variable for seasonal restrictions that did not prevent harvesting outside of the winter months was not significant and was therefore excluded from the final model. Many of the other restrictions related to individual tree species (e.g. oak or pine) and the value of that species may have overshadowed the impact that the restriction had on bidding behavior. Furthermore, between April and mid-July, harvesting for most sales with a significant oak component was restricted and stump treatment to prevent annosum root rot was required for most pine sales. This made it impossible to separate the impact of the restriction from the relative value of the species compared to other species. In order to analyze the impact of these restrictions, one would need to analyze oak and pine sales with these restrictions and other oak and pine sales without these restrictions. Because virtually all of the oak and pine sales were restricted, we could not measure the impact of these restrictions on bid values.

Seasonal timber harvesting restrictions, or the absence of these restrictions, is not the only factor that influences bid results. Obviously, timber volume and quality are paramount in determining bid prices. As expected, volume per acre was a significant predictor, with each additional ton of volume per acre predicted to increase the winning bid by $24.59 (Table 16). This means that the addition of 6 tons per acre is predicted to change the winning bid by more than the presence or absence of a requirement to harvest a timber sale during the winter or when the ground is frozen.

Timber quality obviously has a large impact on bid values. We suspect that timber stands of exceptional quality receive very high bids regardless of whether or not the sale has a seasonal restriction. Conversely, bids for timber sales with low quality timber may be greatly impacted by seasonal restrictions. Unfortunately, the timber sale prospectuses were generally not detailed enough for us to consistently discern differences in timber quality between sales. We did exclude sales with unusually high or low per acre values to avoid sales that might bias results because of very high or very low quality timber present.

Forty-seven percent of sales were offered in the second quarter, 45% in the fourth quarter, with the remainder offered in the first and third quarters. In the model, the second quarter was used as the reference quarter. The model predicted that sales offered in the fourth quarter would receive a higher winning bid than those offered in the second quarter (Table 16). The reason for this is unclear. Barron et al. (2015) found that in Minnesota, winning bids for sales offered in quarters one through three were higher than those offered in the fourth quarter. They hypothesized that timber buyers would have a greater need for stumpage near the beginning of the year.

The number of bids received may have a significant influence on the value of the winning bid. We did not include the number of bids received in the final model because there was a correlation between the presence of a winter only harvest restriction and the number of bids received. Sales without a winter or frozen ground restriction received an average of 4.78 bids per sale, while sales with this restriction received 3.32 bids per sale ($P<0.001$).

Review of ecological consequences of seasonal harvest restrictions in Wisconsin

Wisconsin is not alone in its application of policies and programs that govern the management of forest resources and essentially, by doing so, setting parameters for timber harvesting and forest management practices that are ecologically sustainable (Kilgore and Blinn 2004). The guidelines were developed to address potential (or existing) environmental effects associated with timber harvesting activities (e.g., reduced water quality, increased risk of disease spread, loss of habitat for wildlife species of concern). Our analysis found that the scale and cost of timber harvesting restrictions in Wisconsin is substantial. However, our subsequent review of ecological consequences resulting from their implementation (or lack thereof), indicates that there has been follow-up analysis to evaluate the tradeoffs associated with implementation of policies and guidelines on the forested landscape, especially in the Lake States.

The subsequent analysis reviews practices and guidelines identified through analysis of timber sales and surveys of participants in the supply chain. In the following pages we discuss 1) potential impacts of restrictions on timber harvest operations, 2) effects of restrictions on forest conditions, and 3) topics for possible future research.

Seasonal impacts related to access and hydrology/soil impacts

According to our analysis, timber availability is highest during winter months (Table 1). This is, in part, out of concern for negative impacts on water quality and soil productivity. Wet sites are often only accessible to machinery and equipment utilized in timber harvesting when the ground is thoroughly frozen. Similarly, limiting heavy equipment traffic on a site to drier seasons of the year is one way to minimize the damage to soil physical properties (WDNR 2011).

In a study comparing summer and winter logged sites in the Chequamegon-Nicolet National Forest (CNNF), Wolf et al. (2008) found there was a significant difference in the types of species found in the ground layer amongst sites that had been logged in different seasons. Winter-logged sites supported more ecologically sensitive native species than summer sites (Wolf et al. 2008). The study concluded that restricting logging to winter months reduced the impacts of these operations on sensitive understory plants, which include some rare plant species (Wolf et al. 2008). For some sites where maintenance of sensitive species is a management consideration, these benefits should be taken into consideration. However, harvest during periods other than winter may increase the prevalence of disturbance related species such as oaks, birches (*Betula spp.*), and pines. Harvest operations, if carried out in late summer or early fall, can provide some of the silvicultural benefits of prescribed fire or soil scarification without the associated cost. Limiting operations to winter can result in undesirable species composition changes for some stands.

Wisconsin has a vast and expansive hydrologic network, with over 15,000 lakes and 12,600 rivers and streams, along with wetlands that extend over 5 million acres (WDNR 2010a). Best management practices (BMPs) have been adopted by many states in order to comply with federal legislation (Clean Water Act 1977 and Water Quality Act 1987) in an effort to reduce nonpoint source pollution (Shy 2006). Forest management practices are predominately regulated at the state level (Neary et al. 2009). Forestry activities conducted on a portion of the 17 million acres of forest lands in Wisconsin, contribute an estimated three to five percent of the state's nonpoint pollution (Shy 2006). In 1995, the state of Wisconsin formalized their forestry BMPs for water quality protection (Cristan et al. 2016). It is important to note that although the BMP program is non-regulatory in Wisconsin, compliance is required for state forests, county forests, private lands enrolled in Managed Forest Law (MFL) since 1995, and lands that are certified as sustainably managed under one or more certification programs (e.g., Forest Stewardship Council (FSC), Sustainable Forestry Initiative (SFI), American Tree Farm System) (Shy 2006). It is also conceivable that forest operations impairing water quality could be subject to scrutiny under state water quality statues.

Cristan et al. (2016) concluded from their review of published literature of forestry BMPs in the United States that when followed they (a) minimize water quality effects of forest operations and (b) effectively reduce stream sedimentation. Their broad review of literature on BMP effectiveness divided research in the US into three geographic regions (number of studies): southern (30), western (31), and northern (20), the latter of which primarily were conducted in the northeastern states with three studies in the Great Lakes region (Cristan et al. 2016). In the one study in Wisconsin identified by Cristan et al. (2016), Shy (2006) found that in the first eight years, correct application of forestry BMPs occurred in 83% of the nearly 500 timber sales monitored and 99% of those instances resulted in no adverse impacts to water quality. This is similar to the conclusion of Cristan et al. (2016) that, when compared to prior practices, BMPs improved water quality in 80-90% of the reported analyses. Adverse impacts to water quality were observed 71% of the time when BMPs were not properly applied and these generally resulted in minor impacts (Shy 2006). Our analysis suggests that there is a lack of applied research, particularly in the Lake States, with regards to ecological benefits (and costs) of BMPs when compared to economic costs (and benefits) of their implementation. Anderson and Lockaby (2011), Lang and Mendell (2012), and Cristan et al. (2016) also noted this gap.

Maintenance of soil productivity is a major consideration in forest management. (WDNR 2011). Soil productivity is a function of physical, chemical, and biological properties, and most of the concerns related to forest growth result from impacts to soil physical properties (WDNR 2011). The susceptibility of soils to compaction and rutting is dependent on texture and moisture content. Saturation of soils occurring on upland sites during spring and early summer months, immediately following heavy rains, and in the fall before freeze-up, leads to increased susceptibility to compaction, puddling, and rutting. Activities taking place on adjacent or connecting parcels, concerns regarding soil disturbances (particularly related to the subsequent impact on water quality), and the underlying composition and structure of the soil may limit harvest and transportation access to the winter months. Application of an efficient system of skid trails, forest roads, and landing(s) are supported by BMPs. Proper planning of roads, landings, and skid trails will limit the degree of disturbance on the landscape, and to the underlying soil, by limiting the extent of the area that might be adversely affected by heavy equipment (Stuart and Edwards 2006).

Oak wilt

The state of Wisconsin has developed guidelines to prevent the spread of oak wilt. These guidelines are mandatory on state, county, and MFL (or other forest tax law) land and are recommended for use on other forestland. The guidelines suggest that oak wilt infected stands or stands that are in and within 6 miles of a county with oak wilt should apply harvest restrictions from April 1 – July 15 in the southern area of the state or from April 15 – July 15 in the northern area of the state (WDNR 2015b). As of 2015, the map of known counties with oak wilt only excluded Door, Kewaunee, Manitowoc, Calumet, Sheboygan, Forest, Taylor, Price, Iron, Ashland, Bayfield and Douglas Counties (WDNR 2015b).

This restriction is in place to prevent the spread of the fungus that causes oak wilt by nitidulid beetle. These insects are attracted to oak wilt mats formed on recently killed trees, where they pick up spores which can be transmitted to healthy trees via xylem-penetrating wounds (Juzwik et al. 2011). Studies indicate that the nitidulid beetles transmission to wounds is highest during spring months (e.g., Juzwik et al. 2004) and the difference in timing of the restriction in Wisconsin is due to the difference in climate (start of spring) in regions located south and north of the vegetative tension zone. Prevention of spread via transmission by way of insects is thus best accomplished by avoiding wounding uninfected oaks through means such as cutting branch ends, creating fresh stump surfaces, and wounding stems during times of the year when the insect is active and oaks are susceptible to infection (Juzwik et al. 2011). When harvest activities occur outside of the critical time period, the risk of infection significantly decreases and a recent isolated study of harvesting activities in WI's Central Sands region found no evidence of overland oak wilt infection associated with harvesting activities in stands with operations conducted in mid-summer and early fall (WDNR 2010b).

The fungus *Ceratocystis fagacearum* is the cause of oak wilt and was discovered in Wisconsin in the early 1940s (Juzwik et al. 2011). Spread of the fungus either occurs via aboveground vectors, such as nitidulid beetles, or belowground through root grafts that form among oaks of like species (Juzwik et al. 2011). New disease pockets can be established when fresh xylem-penetrating wounds resulting from damage or injury caused by logging, pruning, felling, or other natural causes are visited during spring and early summer by *C. fagacearum* contaminated beetles (Juzwik et al. 2011). Wilson (2001) suggests that spread of the fungus via grafted root systems in oaks of the upper Midwest, occurs at a rate of less than 50 feet per year. Stands with higher compositions of red oak are more likely to experience mortality by root graft transmission and exhibit greater average number of infected trees within pockets (Menges and Loucks 1984). A greater diversity of tree species in a stand results in a lower severity of oak wilt (Wilson 2001). Trees infected with the fungus eventually die, exhibiting symptoms of infection ranging from leaf browning to crown die-back to development of fungal mats, with predominant susceptibility occurring amongst oaks of the red oak subgroup (Juzwik et al. 2011). Oak wilt is an aggressive forest pathogen, with mortality often experienced within a few months following expression of symptoms (Wilson 2001), especially for the red oak species.

Stands with oaks that have experienced mortality due to oak wilt will have open spaces and dead trees (coarse woody debris and snags) that provide nesting and feeding sites for wildlife. The oak will be eliminated in the stand by the disease as oak wilt-killed trees do not successfully sprout (Menges and Loucks 1984). A site is often brushy for up to 10 years following the death of overstory oak trees, a condition that attracts many birds (warblers [*Vermivora spp.*], grosbeaks [*Coccothraustes spp.*], cuckoos [*Coccyzus spp.*], cardinals [*Cardinalis spp.*]), small mammals (shrews [*Blarina spp.*]), and game species (ruffed grouse [*Bonasa umbellus*], rabbit [*Oryctolagus spp.*], and deer [*Odocoileus spp.*]) (Carlson et al. 2010). However, when the oaks are alive, they produce a good to excellent acorn seed crop every two to five years which are eaten by a large variety of birds and mammals (Burns and Honkala 1990).

Oak/hickory (*Carya spp.*) forests are the most common of the forest types found in Wisconsin, constituting 4.4 million acres, and these forests consist primarily of sawtimber trees (greater than 11.1 in. dbh) (Perry 2015). The red oak group is an important contributor to the overall products coming from the forest. In 2008, the red oak group accounted for 16% of the total Wisconsin sawlog harvest and ranked fifth (of 14 species groups) for industrial roundwood production (Haugen 2013). Northern red oak (*Quercus rubra*) and white oak (*Quercus alba*) are among the top ten tree species by net volume in Wisconsin, with approximately 2,068 and 870 million ft^3 respectively (Perry 2015). Roughly 55% of the growing stock volume of select red oak and other red oak species on timberland (using inventoried lands from 2005-2009) in Wisconsin is privately held (FIDO 2016).

Perry et al. (2012) concluded that oak forests in the state of Wisconsin exhibit a disparity in age classes on medium to high quality sites, where regeneration is poor for young oak forests. Limiting harvesting of oak to winter-only will result in less ground disturbance within the forest stand. Logging disturbance tends to assist in oak regeneration by creating conditions conducive to the establishment of oak (Demchik et al. 2013).

Recreation

Over half of Wisconsin's forest lands are owned by family forest owners, with over 60% of this area having owners who indicate that their primary ownership objectives for the property are aesthetics, hunting and fishing (Perry et al. 2012). If such a landowner were to conduct timber management activities, such as harvesting, on their property and wanted to avoid conducting operations during the gun deer season scheduling of activities would be restricted from mid- through late-November, with archery and crossbow season extending from mid-September through the first weekend of the new year (WDNR 2015g). As previously stated, this would severely limit the ability to harvest oak stands in Wisconsin, which are already subject to oak wilt restrictions that extend from April 1(or April 15) through July 15 for the south (or north) zones. Public agencies also consider recreation impacts from timber harvest. Attempts to mediate impacts often include both seasonal restrictions and communication with various stakeholder groups (WDNR 2015c).

The management of forest resources by public entities is often specifically directed or focused on providing multiple benefits including recreation, as it is specifically referenced in legislative language directing such management (e.g., National Forest Management Act 1976, WI s28.04, WI s28.11). Approximately one-third of the forests of Wisconsin are publically owned controlled by federal, state, county, and municipal entities that have these multiple use management objectives. Similarly, publically sponsored programs also can also have management objectives focusing on ecological, economic, and recreational benefits, as well as others.

An example of such a program is the Managed Forest Law (MFL) program in Wisconsin. MFL encourages sustainable forestry practices via an incentive program (WDNR 2015f). Private ownerships enrolled in MFL can choose to allow public access for recreation activities by designating property as "open", in return receiving a lower property tax rate compared to closed lands and non-enrolled parcels. Ownerships enrolled in the MFL are limited to a maximum of 160 acres of "closed" land (lands enrolled prior to 2005 were restricted to 80 acre "closed" maximum). Lands designated as "open" are for purposes of hunting, hiking, fishing, sightseeing, and cross country skiing within bounds of the program (WDNR 2015f). In aesthetic management zones, "hardwood logging should be conducted when residual trees are leafless in order to reduce felling damage and eliminate persistent foliage in the tops, and felled tops and slash should not be in excess of 1.5 ft. of the ground surface" (WDNR 2015c). Management operations should be avoided during periods of peak recreational use when possible and timing and coordination of activities should consider auditory and visual impacts (WDNR 2011).

However, timber harvesting activities can be beneficial to recreational uses, particularly hunters. For instance, a common game bird species, the ruffed grouse, depends on food and cover provided by a group of trees and shrubs present in recently disturbed (early-successional) landscapes. Similarly, white-tailed deer (*Odocoileus virginianus*) prefer relatively young aspen stands as a food source, and aspen is an excellent example of a shade-intolerant, short lived tree. Historically, conditions for short-lived tree species were provided by periodic fires, but with increasing urbanization, such disturbances are often suppressed and suitable conditions for short-lived trees are now largely produced by timber harvests. Although quaking aspen (*Populus tremuloides*), a common commercially utilized short-lived species, is still one of the most voluminous species in Wisconsin, average annual net growth rate is lower than the average annual harvest removals (Perry 2015). Fewer trees in Wisconsin are in the small diameter-size classes (a typical indicator of early successional forests) and much of the existing growing stock volume in short-lived species is concentrated in older trees (Perry et al. 2012). Variability and variety in stand composition and structure across the landscape are desirable in terms of providing habitat for most wildlife species, as well as providing different types of recreational opportunities. Operational areas such as haul roads and landings used for timber harvesting could be utilized after harvest for recreational purposes (WDNR 2015c).

Annosum root rot

The state of Wisconsin has also developed guidelines to prevent the spread of Annosum root rot. Treatment of pine stumps is recommended during harvests that occur under non-frozen ground conditions, i.e. from April 1 – November 30 (the season extends if there is an unusually warm winter or shortens if heavy snow cover occurs beyond the winter period), when stands undergoing harvest occur within 25 miles of a stand confirmed with Annosum root rot and density of pines is 50% or more. Treatment is recommended as effective prevention of the pathogen on fresh uninfected fresh cut stumps is accomplished via application of a fungicide, either Sporax (sodium tetraborate decahydrate) or Cellu-Treat (disodium octaborate tretrahydrate) are approved and available for use in Wisconsin (WDNR 2013).

Annosum root rot is caused by the fungus *Heterobasidion irregular*e. First discovered in Wisconsin in 1993, its presence has been confirmed mostly in counties constituting a band extending from the extreme southwest Grant, Columbia, and Richland counties northeast to Marinette and Oconto (excepting Menominee); also including LaCrosse, Trempealeau, Buffalo, Dunn, Taylor, Green, Walworth, Waukesha, and Jefferson. It primarily affects conifers and is most damaging in plantation-grown pines where stumps of trees were left and root connections occur, as the pathogen attacks the cambium of the host trees, resulting in wood decay and eventual death (Robbins 1984). Infection has been observed on red pine *(Pinus resinosa*), eastern white pine (*Pinus strobus*), and jack pine (*Pinus banksiana*) trees in the overstory, while fruiting bodies have been observed in the understory on the previously listed trees, along with balsam fir (*Abies balsamea*), white spruce (*Picea glauca*), eastern redcedar (*Juniperus virginiana*), red and white oaks (*Quercus* spp.), black cherry (*Prunus serotina*) and buckthorn (*Rhamnus* spp.). Mortality has been observed or suspected primarily in the pines, balsam fir, and eastern red cedar (WDNR 2013).

Infected trees exhibit a fruit body produced by the fungus near the soil line, while spores primarily colonize on fresh stumps (Robbins 1984). In Wisconsin, observed introductions of Annosum root rot are primarily via stump infections. Upon infection of the stump, the pathogen can be transmitted via root contact to nearby residual trees, the latter of which will typically start to exhibit mortality three to eight years after the stand was thinned (Robbins 1984).

The presence of annosum root rot will result in mortality to pine stands, particularly managed stands, and thus care should be taken not to introduce or promote further spread of the pathogen when conducting management activities, as the fungus primarily spreads through infection of the stump surface. This can be done through concentration of pine harvests during frozen conditions, when a number of constraints are also lifted for deciduous stands, or treating harvested stumps during warmer portions of the year. Recent inventory of Wisconsin forest resource suggests that annosum root rot is not currently having significant impact on the two most voluminous pine species as both eastern white pine and red pine had average annual net growth of more than 75 million ft^3/year, along with relatively low average annual mortality (roughly 6 and 3 million ft^3/yr., respectively) (Perry 2015). Robbins (1984) suggests that stands with a history of annosum root rot are subject to ≤ five percent seedling mortality if planted with pine immediately after harvest.

Rare/endangered species

In our study, we found sales with seasonal restrictions related to rare, endangered, or protected animal species, often indicated by a Natural Heritage Inventory (NHI) hit. Federally listed species are protected by the Endangered Species Act of 1973, which prohibits “take” (defined as harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect). Modification of habitats that results in harm to a federally listed species can be interpreted as “take,” although incidental take as a result of normal land management activities can be authorized following submission of a habitat conservation plan. Wisconsin also has an endangered and threatened species list and has also identified species of greatest conservation need in its wildlife management action plan (WDNR 2005).

Five species were listed as NHI hits on timber cutting notices: wood turtle, Blanding's turtle, Northern long-eared bat, Karner blue butterfly, and northern goshawk. Table 17 summarizes restricted periods for timber harvesting activities associated with these species, with black indicating months when activities are restricted or larger areas are impacted by restrictions and gray indicating months when restrictions impact smaller areas or there is a lower risk of impact. In the following sections we discuss the species, restrictions, and gaps in knowledge.

Table 17: Summary of commonly restricted periods for timber harvesting activities in Wisconsin. Black indicates months when timber harvesting is restricted and/or larger areas are protected, while gray portions indicate months when smaller areas are impacted by timber harvesting restrictions or there is a lower risk of impact.

Rationale	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Wood turtle												
Blanding's turtle												
Northern goshawk												
Northern long-eared bat												
Oak wilt												
Annosum root rot												
Hydrology/soil*												
Recreation*												

* These restrictions are specific to a site and/or preferences of the landowner and thus can be variable in their timing of application.

Turtles

Presence of, or suitable habitat for, wood turtle and Blanding's turtle result in avoidance measures and management guidance associated with timber harvesting practices occurring on forested lands. Wood turtles are listed as threatened, while Blanding's turtles are listed as a special concern species in Wisconsin.

Typically, two strategies are employed to avoid take of wood turtles in Wisconsin. Activities in areas with wood turtle occurrence or suitable habitat should be conducted during the turtles' inactive season (November 1 through March 14)[1] or follow avoidance measures from March 15 to October 31 (Kapfer 2015). If suitable habitat cannot be avoided, an avoidance area buffer, where activities cannot occur is measured from a suitable wood turtle stream or river, the width varies during this time period. From March 15 – May 14 and again from September 16 – October 31, a buffer of up to 246 ft. is required, while from May 15 – September 15, the buffer increases to 984 ft. (Kapfer 2015).

Most harvesting activity in wood turtle areas is limited to winter harvests, as harvest areas with 100% and 50% natural snow cover within and greater than 100 feet from suitable wood turtle steams, respectively, can have activities at that time. The second strategy employed is to install exclusion fencing around upland project sites during the wood turtle's non-active season in order to conduct work within the fenced area any time of year. Exclusion fencing adds expense to a project, but is very effective at preventing turtles from entering an area if properly installed and maintained (Kapfer 2015). "Pine plantations are not considered wood turtle habitat if they exhibit all of the following conditions: the stand has reached stem exclusion stage (approximately > 25 yrs); less than five percent of the understory is occupied by tree seedling/saplings, shrubs, and/or herbaceous plants; and equipment operators have a clear view within the stand" (Kapfer 2015).

Wood turtles are found from northern Wisconsin to Brown, Outagamie, and Winnebago counties in the southeast, extending along through the southwest portion of the state to Grant, Iowa, and Columbia counties (excluding Richland) (Kapfer 2015). Of the aquatic turtles in the upper Midwest, wood turtles are more terrestrial in their habitat and makes use of areas along streams and uplands within wooded and semi-wooded areas (Endangered Resource Review Program (ERRP) 2015). Preferred habitat includes moderate- to fast-flowing streams or rivers that have sand, gravel or cobble substrate with limited silt or muck (Harding 1997). Various studies have indicated that the wood turtles' range of travel from their overwintering streams is in excess of 200 m and in some cases as far as 600 m (for resources see: Kapfer 2015). Their ability to range far from overwintering streams and known utilization of a variety of habitats ranging from closed-canopy forests to more open areas during active periods has resulted in management guidelines, avoidance measures, and a Broad Incidental Take Permit/Authorization for Common Activities (BITP/A). The BITP/A was developed to find greater flexibility for forestry practices in Wisconsin (ERRP 2015) as a result of "take" (both in terms of damage to the animal and its habitat) being prohibited as a result of the state threatened status.

Though there is a risk, albeit low, of direct mortality to wood turtles during forest harvesting, harvesting also has the potential to benefit the species by providing favorable conditions for foraging, nesting, and incubation. Openings and open stand conditions that result from partial harvests provide conditions for successful nesting, regulation of body temperature (both sun and shade in forested areas), and production of berries (e.g. *Rubus* spp.), which is a major food source (ERRP 2015).

[1] The dates herein are updated according to annual weather conditions on a yearly basis available through the Wisconsin DNR at http://dnr.wi.gov/topic/WildlifeHabitat/Herps.asp#regs (last accessed 12/2015).

On forested parcels adjacent to wood turtle habitat where a landowner wants to avoid harvest during hunting season (below), operability is limited to four nonconsecutive months. This allows little time for harvesting stands containing oak and promoting a viable seed crop via scarification. Logging conducted during winter will not scarify the soils as would operations during other times of the year. Thus, harvesting oak stands solely during winter will create conditions that favor advance regeneration of shade tolerant species and reduce the likelihood of oak reestablishment (Menges and Loucks 1984).

The timing of restrictions designed to avoid take of Blanding's turtle are designed to avoid impact on suitable habitat. Thus, uplands and wetlands shallower than 3 feet can be harvested from October 16- March 14. Installation of exclusion fencing should occur during the previously referenced inactive period in order to conduct work within properly maintained fenced areas at any time of the year. Work conducted within 900 ft. of a wetland or water body considered to be nesting habitat, including installation of exclusion fencing, should be conducted from October 16-May 19 (Komp and Hay 2015).

The Blanding's turtle is a species of special concern in Wisconsin and occurs throughout the state, except for the far north-central portion of the state. Blanding's turtles are most commonly encountered in shallow, slow-moving waters with abundant vegetation, e.g., grassy marshes, slow-moving rivers, shallow lakes and ponds, and mesic prairies (Komp and Hay 2015). The turtles typically nest in open areas with sandy soils within 900 ft. (275m) of a wetland or water body and may occasionally be encountered in uplands if moving between wetlands, nesting sites, and overwintering sites (Komp and Hay 2015). They begin to emerge from overwintering sites as early as March and migration distances can be up to several miles during the active season (Komp and Hay 2015). Management that is designed to recover, maintain or improve grassland, prairie, or savanna ecosystems may prove beneficial to the species, there are recommended guidelines specified by the WI DNR for these activities (see Komp and Hay 2015). The maximum active period for the species is March 15 – October 15 in Wisconsin (Komp and Hay 2015).

Northern goshawk (Accipiter gentilis)

Projects occurring where northern goshawk elements or suitable habitat occur should conduct activities in fall and winter, outside of the breeding season from February 1 to July 31 (Woodford and Van Doren 2013). Aside from avoiding active breeding season of northern goshawk, if known nesting areas are present forest management activities should follow all of the following four avoidance measures: establish a minimum radius 660 ft. no-cut buffer around active and alternate nest trees (typically range from one to five in relatively small forest stands), retain 70% of the nest stand area's pre-harvest basal area when conducting uneven-aged harvests or thinnings, limit activities within the nest area (1000 ft. radius) to periods outside of February 1 to July 31 (February 1 – May 31 is most critical), and limit disturbances within the nest area to one year during a timber sale (Woodford and Van Doren 2013).

A study by Bruggeman et al. (2011) to determine goshawk status in the western Great Lakes bioregion, which included portions of Wisconsin, suggested that throughout the bioregion there is sparse but wide distribution of the bird. The study also indicated a strong preference (74% of detections) for high amounts of canopy cover (canopy closure >75%) amongst recorded goshawk habitats, most of which were surrounded by northern hardwood and aspen/white birch forest types (Bruggeman et al. 2011). With the exception of Barron and Polk, all counties in northern WI along with Clark, Wood, Portage, Door, Jackson, Waushara, Monroe, Juneau, Marquette, and Sheboygan have verified nesting records (Woodford and Van Doren 2013). Rosenfield et al. (1998) found that a majority (78%) of nests in Wisconsin were built in deciduous trees with a mean diameter of 16.1 in., mean canopy height of 82 ft. and a mean 171.2 trees/acre.

Despite the restrictions on season of harvest activities, forest management and silvicultural practices can benefit northern goshawks if they maintain moderate to high levels of canopy closure, preserve trees that are >15 in. dbh, and conserve large contiguous blocks of hardwoods, mixed and coniferous stands (Woodford and Van Doren 2013). Generally, uneven-aged management and practices that increase diversity of forest stands across large blocks of land improve conditions for northern goshawk (2013).

Bats

Four cave dwelling bats are on the Wisconsin threatened species list, primarily due to the threat posed by white-nose syndrome caused by the fungus *Psuedogymnoascus destructans*, including big brown bat (*Eptesicus fuscus*), eastern pipistrelle (*Perimyotis subflavus*), little brown bat (*Myotis lucifugus*), and northern long-eared bat (*Myotis septentrionalis*). The northern long-eared bat received protection as a threatened species under the Endangered Species Act with a 4(d) rule effective February 16, 2016 (USFWS 2016). There is a broad incidental take permit and broad incidental take authorization conservation plan covering state listed cave batswhich will not apply to the northern long-eared bat unless specifically approved by the US Fish and Wildlife Service. According to the BITP/A, all covered cave-dwelling bats utilize forest habitats to some extent, particularly cavities for roosting in the summer, while northern long-eared bat is also known to forage in upland forest habitats when not hibernating in caves or mines during the winter months (WDNR 2015f).

The BITP/A for big brown bat, eastern pipistrelle, and little brown bat covers forestry activities, among other projects that may result in an incidental take of these cave bats. There are no restrictions for tree cutting, however consideration for protection of snags or dying trees, particularly from June 1 – August 15 is recommended. Wisconsin is located in the white-nosed syndrome buffer zone per the 4d rule for the northern long-eared bat, currently listed as a federally threatened species. Counties with white-nosed syndrome infected hibernacula in the state include Crawford, Grant, Lafayette, Iowa, Richland, Dane and Dodge (USFWS 2015). The 4(d) rule exempts incidental take from forest management practices and tree removal projects as long as activities occur more than 0.25 mile from known hibernacula and avoid cutting or destroying known, occupied maternity roost trees or any other trees within a 150-ft radius from the maternity roost tree, from June 1 through July 31 (USFWS 2016). Forest management benefits northern long-eared and other bats by maintaining forest areas (rather than conversion to other use), particularly if care is taken to avoid roost trees and preserve snags and dying trees in managed stands.

Karner blue butterfly

The Karner blue butterfly has been a federally protected endangered species since its listing in 1992. Wild lupine (*Lupinus perennis*) is the only known larval food plant of the Karner blue butterfly (Kbb), which is also dependent on nectar plants. Historically, these plants occurred in savanna and barrens habitats typified by dry sandy soils, while presently they occur in remnants of these habitats as well as other dry open areas, like roadsides, military bases, and some forest lands (USFWS 2003). Loss of habitat via development and canopy closure are primary limiting factors, thus for maintenance of viable populations of Kbb, there needs to be a balance between closed and open-canopy habitats (USFWS 2003). There are no specific restrictions on timing of activities associated with this species; the Kbb recovery plan states that, in some parts of Burnett, Jackson, Juneau, and Wood counties, forest management activities conduced in the summer, such as harvest, road building and maintenance, site preparation, tree planting, slash burning, and others appear to be beneficial to both lupine and the Kbb (USFWS 2003).

Wisconsin has developed a Habitat Conservation Plan (HCP) that includes protocols for both timber harvesting and timber stand improvement activities. The Kbb HCP recognizes that newly established forest stands up to about 15 years of age are potential habitat, after which most fully stocked stands have developed crown closure such that shade-intolerant plants such as lupine and nectar plants are significantly reduced (WDNR 2007). The HCP describes measures that should be taken in order to avoid and minimize take of Kbb and applies to sites occupied by Kbb and to lupine sites in the High Potential Range (WDNR 2007). The High Potential Range in Wisconsin primarily includes areas in Burnett, Eau Claire, Chippewa, Clark, Jackson, Monroe, Wood, Juneau Adams, Portage, Waupaca, Waushara, Marquette, and Green Lake Counties. Avoidance measures include not operating in areas previously described; while minimization measures for timber harvest include pre-management surveys on pre-planned harvest sites and, on occupied sites, dispersing slash piles, leaving scattered pockets of trees, not disturbing scattered occupied sites, and potentially conducting post management surveys (WDNR 2007).

Seasonal weight limits

The concern that prompted seasonal weight limits was potential damage caused to roads and highways from hauling heavy loads when roads are vulnerable to damage because of spring thaw. Wisconsin has specific regulations for vehicles or combination of vehicles that are exclusively transporting peeled or unpeeled forest products cut crosswise. The gross weight imposed on Class A highways cannot exceed 21,500 lbs. or 37,000 lbs. for 2 axles less than or equal to 8 feet apart or a weight of 4,000 lbs. more than is shown in the maximum gross weight table but not to exceed 80,000 lbs. for groups of 3 or more consecutive axles more than 9 feet apart (Chapter 348.15.3 b, r and c in Wisconsin State Legislature Statues, Wisconsin Department of Transportation 2015). On class B highways, vehicles or combination of vehicles, with the exception of vehicles that are exclusively transporting peeled or unpeeled forest products cut crosswise during winter months when highways are so frozen that no damage may result from transportation, are subject to limits that are 60% of the weights authorized for Class A highways (348.16 (2) and s. 348.175). Roadway sections that are too weak to withstand the legal limit during the spring freezing and thawing period have reduced weight limits typically running from the second week in March until late April or early May (spring breakup). These weight limits are also posted by county and township authorities (Wisconsin DOT 2015).

These are slightly more stringent than the weight limits imposed in neighboring Great Lakes states. In Minnesota, forest products transported on six-axle (or more) vehicles are limited to 90,000 lbs. (pulpwood is limited to 82,000 lbs. with the same axle configuration) (MN House

2014). In Michigan, truck and trailer or semi-trailer designed and used to transport saw logs is limited to a gross weight of 164,000 lbs. (MDOT 2014).

Gibeault and Coutu (2014) found that amongst load trucks operating in the Lake States, a high percentage included loaders. Loaders effectively add to the overall weight and thus subtract from the payload that can be transported from the forest to a processing facility at one time, as a result of the previously referenced weight limits. The majority of logging operations in Wisconsin in a study on operations conducted during 2010 contracted less than 30% of their trucking (Rickenbach et al. 2005), thus forest managers and loggers take the seasonal weight limits into consideration when planning and executing management activities.

Recommendations

Timber sale preparation improvement:

- **Segregate winter units from summer units during timber sale preparation**. During our analysis of timber sales on public land, we observed that some timber sales contained units that were restricted to winter or frozen ground conditions, while the same sale contained acres that could be harvested at any time. This type of sale gives a timber buyer two options: harvest the entire sale during the winter, or move to the same sale twice. Moving to the same sale twice doubles the moving costs assigned to the sale, which can easily exceed $500 per move (Conrad 2014). Including winter or frozen ground units with unrestricted units is likely to result in lower stumpage prices for the seller and reduces timber availability during the summer and fall.

- **Avoid unnecessary restrictions**. Our timber sale analysis found that 44% of sales across all ownership categories were subject to soil and/or hydrological restrictions (Table 2). While we cannot definitively say that some of these restrictions were unnecessary, we suggest caution when applying restrictions. A better approach to protect soil and water may be to specify what constitutes unacceptable soil disturbance and monitor harvesting operations to ensure that soil disturbance is within established guidelines.

Consider unintended consequences of seasonal restrictions:

- **What are the ecological consequences of the concentration of pine harvests during the spring and early summer?** Because of the unavailability of hardwood during the spring and early summer, many loggers shift their harvests to pine during this period. The impact of this on the pine ecosystem in Wisconsin is unknown.

- **Disturbance is desirable for regeneration of disturbance-dependent species like oak and pine**. The concentration of timber harvests during winter means reduced soil disturbance during harvest because the ground is frozen and covered with snow. Many species (e.g. oak, birch, pine, etc.) require soil disturbance in order to regenerate. The reduction in soil disturbance may have the unintended effect of reducing the prevalence of these species in Wisconsin.

Preparation of future policies, guidelines, and restrictions:

- **Maximize flexibility in the application of guidelines and restrictions**. The application of seasonal timber harvesting restrictions clearly imposes costs on Wisconsin forest landowners, loggers, and forest industry. Allowing as much flexibility as is practical should limit the impact of restrictions on Wisconsin's wood supply chain. For example, guidelines that focus on end-results rather than specific practices may reduce costs compared to less flexible guidelines or restrictions. Similarly, providing foresters and landowners with a suite of potential methods for protecting the resource allows flexibility and may reduce costs. An example of this can be seen from the annosum root rot guidelines, which allow timber to be harvested during the winter without stump treatment or harvest to occur outside winter with application of Sporax or CelluTreat.

- **Consider the cumulative costs of guidelines and restrictions**. Guidelines such as those to prevent annosum root rot are not considered a "restriction" because it is only a "cost". However, each restriction imposes a cost, directly or indirectly, and while each individual restriction may impose a small cost, the cumulative impact of a series of restrictions can be substantial. At some point, excessive costs may encourage some landowners to convert forestland to some other use. Likewise, persistent differences in delivered costs between regions as documented by Gibeault and Coutu (2014) could result in the immigration of Wisconsin's forest industry to lower cost regions, especially for firms that already operate in multiple regions. This would cost Wisconsin jobs in the forest products sector and disincentivize forest management.

- **Improve communication between public sector, consulting, and industrial foresters.** The forester survey documented differences of opinion in regard to the effectiveness and cost efficiency of seasonal timber harvesting restrictions. Better communication between foresters can lead to better understandings of the rationale for the restrictions and the cost of their application. There may be an opportunity for professional associations (e.g. Society of American Foresters) to facilitate this conversation.

- **Multi-year studies are needed to evaluate the effectiveness of restrictions, guidelines, and policies.** While the restrictions discussed in this study were put in place to address concerns, in many cases research supporting some aspects of these policies is limited. For example, Cristan et al. (2016) found only three BMP effectiveness studies from the Lake States region compared to 30 from the U.S. South. Likewise, we found limited research relating to the effectiveness of other practices put in place to protect forest resources. While this study demonstrated the cost of various restrictions at a point in time, most benefits associated with these restrictions would be expected to accrue over the course of many years, and therefore long term studies are necessary to evaluate whether these practices are effective. The publication of guidelines or the application of restrictions demonstrates effort to solve a problem or protect a resource; however, they do not, in and of themselves, demonstrate that the problem has been solved or the resource protected. Outcomes should be measured to determine: 1) whether the practice or policy was implemented, 2) whether the practice or policy was effective, and 3) whether the benefits of the practice or policy exceed the associated costs.

References

Anderson, C.J. and B.G. Lockaby. 2011. Research gaps related to forest management and stream sediment in the United States. *Environ. Mgmt.* 47:303-313.

Anderson, N. and R. Germain. 2007. Variation and trends in sawmill wood procurement in the Northeastern United States. *For. Prod. J.* 57(10):36-44.

Armstrong, J.S. and T.S. Overton. 1977. Estimating nonresponse bias in mail surveys. *J. Mark. Res.* 14(3):396-402.

Barron, P., M. Kilgore, and C. Blinn. 2015. Does payment method affect stumpage price? In: Proc. 38th *Annual Council on Forest Engineering Meeting*; Lexington, KY. 12 p.

Bauer, D.M., W.C. Paton, and S.K. Swallow. 2010. Are wetland regulations cost effective for species protection? A case study of amphibian metapopulations. *Ecol. Appl.* 20(3):798-815.

Blinn, C.R., A.M. Alden, and P.V. Ellefson. 2001. Timber harvester perceptions of costs and benefits from applying water quality BMPs in north-central USA. *International Journal of Forest Engineering* 12(1):39-51.

Brinker, R.W., J. Kinard, B. Rummer, and B. Lanford. 2002. *Machine rates for selected forest harvesting machines*. Circular 296 (revised). Alabama Agricultural Experiment Station, Auburn University, Auburn, AL. 32 p.

Bruggeman, J.E., Andersen, D.E. and J. E. Woodford. 2011. Northern Goshawk monitoring in the western Great Lakes bioregion. *Journal of Raptor Research* 45:290-303.

Bureau of Labor Statistics. 2014. May 2014 state occupational employment and wage estimates Wisconsin. Available online at http://www.bls.gov/oes/current/oes_wi.htm#45-0000; last accessed January 4, 2016.

Burns, R.M. and B.H. Honkala. 1990. Silvics of North America volume 2: Hardwoods. USDA Forest Service, Agriculture Handbook 654.

Carlson, J.C., A.J. Martin, and K. Scanlon. 2010. Lake States woodlands: Oak wilt management – what are the options? University of Wisconsin-Extension G3590. 6p.

Cristan, R., W.M. Aust, M.C. Bolding, S.M. Barrett, J.F. Munsell, and E. Schilling. 2016. Effectiveness of forestry best management practices in the United States: Literature review. *For. Ecol. Mgmt.* 360:133-151.

Conrad, J.L., IV. 2014. Adapting to a changing landscape: how Wisconsin loggers persist in an era of parcelization. *For. Prod. J.* 64(7/8):273-280.

Conrad, J.L., IV, M.M. Vokoun, S.P. Prisley, and M.C. Bolding. 2015. Logging capacity utilization in Wisconsin. In: Proc. 38th *Annual Council on Forest Engineering Meeting*; Lexington, KY. 11p.

Dahal, P. and S.R. Mehmood. 2005. Determinants of timber bid prices in Arkansas. *For. Prod. J.* 55(12):89-94.

Demchik, M.D., T.N. Radke, and M.Z. Arik. 2013. Observations of the impact of soil scarification and fire on oak accumulation on shelterwood sites. *North. J. Appl. For.* 30(2):92-94.

Dillman, D.A. 2007. *Mail and internet surveys: the tailored design method*. 2nd ed. Wiley, Hoboken, N.J. 523 p.

Egan, A., D. Taggart, and I. Annis. 2007. Effects of population pressures on wood procurement and logging opportunities in northern New England. *North. J. Appl. For.* 24(2):85-90.

EERP. 2015. *Wisconsin Department of Natural Resources Broad Incidental Take Permit/Authorization for common activities: Forest management and Wood turtle (Glyptemys insculpta)*. Available online at: http://dnr.wi.gov/topic/erreview/documents/woodturtleforestryprotocol.pdf; last accessed 29 December 2015.

Gallagher, T., B. Shaffer, and B. Rummer. 2008. Using short-rotation, intensively managed hardwood plantations as "green" inventory for southeastern U.S. pulp mills. *TAPPI* 8(3):15-21.

Gibeault, F.M. and P.J. Coutu. 2014. *Wood supply chain component costs analysis: a comparison of Wisconsin and U.S. regional costs*. Steigerwaldt Land Services, Inc. and Forest2Market, Inc. 41 p.

Greene, W.D., J.H. Mayo, C.F. deHoop, and A.F. Egan. 2004. Causes and costs of unused logging capacity in the southern United States and Maine. *For. Prod. J.* 54(5):29-37.

Haight, R. G. 1995. Comparing Extinction Risk and Economic Cost in Wildlife Conservation Planning. *Ecol. Appl.* 5(3):767-775.

Harding, J. H. 1997. *Amphibians and reptiles of the Great Lakes Region*. University of Michigan Press, Ann Arbor, MI. 378 p.

Haugen, D.E. 2013. *Wisconsin timber industry-an assessment of timber product output and use, 2008*. Resour. Bull. NRS-78. Newton Square, PA: USDA Forest Service Northern Research Station. 110 p.

IBM Corp. 2012. *IBM SPSS statistics for Windows, version 21.0*. Armonk, NY.

Forest Inventory Data Online (FIDO) 2015. Version 1.5.1.05c. St. Paul, MN: USDA Forest Service, Northern Research Station. Available online at http://apps.fs.fed.us/fia/fido/customrpt/app.html; last accessed January 4, 2016.

Juzwik, J., T.C. Skalbeck, and M.F. Neuman. 2004. Sap beetle species (Coleoptera: Nitidulidae) visiting fresh wounds on health oaks during spring in Minnesota. *For. Sci.* 50(6):757-764.

Juzwik, J., D.N. Appel, W.L. MacDonald, and S. Burks. 2011. Challenges and successes in managing oak wilt in the United States. *Plant Dis.* 95(8):888-900.

Kapfer, J.M. 2015. Wood Turtle (Glyptemys insculpta) species guidance. Wisconsin Department of Natural Resources Bureau of Natural Heritage Conservation PUB-ER-684. 10p.

Kilgore, M.A. and C.R. Blinn. 2003. The financial cost to forest landowners who implement forest management guidelines: an empirical assessment. *J. For.* 101(8):37-41.

Kilgore, M.A. and C.R. Blinn. 2004. Encouraging the application of sustainable timber harvesting practices: A review of policy tool use and effectiveness in the Eastern United States. *Water, Air, and Soil Pollution:Focus* 4: 203-216.

Kilgore, M.A. and C.R. Blinn. 2005. The impact of timber harvesting and timber sale attributes on stumpage bidding behavior. *North. J. Appl. For.* 22(4):275-280.

Komp, M. and R. Hay. 2015. Blanding's turtle (Emydoidea blandingii) species guidance. Wisconsin Department of Natural Resources Bureau of Natural Heritage Conservation PUB-ER-683. 7p.

Lang, A.H. and B.C. Mendell. 2012. Sustainable wood procurement: what the literature tells us. *J. For.* 110(3):157-163.

Linares-Hernandez, A. and E.M. Wengert. 1997. End coating logs to prevent stain and checking. *For. Prod. J.* 47(4):65-70.

Marshall, E., F. Homans, and R. Haight. 2000. Exploring strategies for improving the cost effectiveness of endangered species management: The Kirtland's warbler as a case study. *Land Econ.* 76(3):462-473.

Maxwell, S.E. and H.D. Delaney. 2004. *Designing experiments and analyzing data*. Lawrence Erlbaum Associates, Inc. Mahwah, New Jersey. 868 p.

Menges, E.S. and O.L. Loucks. 1984. Modeling a disease-caused patch disturbance: Oak wilt in the Midwestern United States. *Ecology* 65(2):487-498.

Michigan Department of Transportation. 2014. Maximum legal truck loadings and dimensions (T-1). Available online at: http://gltpa.org/pdf/mi-leg/T-1-max-load-dim.pdf, last accessed January 4, 2016.

Minnesota House. 2014. Motor vehicle size and weight regulations, Minn. Stat. 169.011, 169.80-169.88. House Research. Available online at: http://www.house.leg.state.mn.us/hrd/issinfo/TruckWeight.pdf, last accessed January 5, 2016.

Montgomery, C. A., G. M. Brown, Jr., and D. M. Adams. 1994. The marginal cost of species preservation: the northern spotted owl. *J. of Environ. Econ. and Manage.* 26:111-128.

Montgomery, R.A., M.H. Pelkki, and S.R. Mehmood. 2005. Use and cost of best management practices (BMPs) and BMP-related sustainable forestry initiative guidelines to Arkansas timber producers. *For. Prod. J.* 55(9):67-73.

Neary, D.G., G.C. Ice, and C. R. Jackson. 2009 Linkages between forest soils and water quality and quantity. *For. Ecol. Mgmt.* 258:2269-2281

Perry, C.H. 2015. *Forests of Wisconsin, 2014*. USDA Forest Service Resource Update FS-43. 4p.

Perry, Charles H.; Everson, Vern A.; Butler, Brett J.; Crocker, Susan J.; Dahir, Sally E.; Diss-Torrance, Andrea L.; Domke, Grant M; Gormanson, Dale D.; Herrick, Sarah K.; Hubbard, Steven S.; Mace, Terry R.; Miles, Patrick D.; Nelson, Mark D.; Rodeout, Richard B.; Saunders, Luke T.; Stueve, Kirk M.; Wilson, Barry T.; Woodall, Christopher W. 2012. *Wisconsin's Forests 2009.* Resour. Bull. NRS-67. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 62 p.

Prentiss and Carlisle. 2015. Timber mart north price report October 2014 – March 2015. *Prentiss and Carlisle* 21(1): 10 p.

Prisley, S.P., M.M. Vokoun, J.L. Conrad IV, and M.C. Bolding. 2014-2015. Wisconsin wood supply assessment. Research proposal funded as part of the Wisconsin Forest Practices Study.

Quillin, S. 1994. Effective chip pile storage design reduces pulp variation, improves mill profits. *Pulp & Paper*. Available online at http://www.risiinfo.com/db_area/archive/p_p_mag/1994/9402/94020111.htm; last accessed January 7, 2016.

Rickenbach, M., M. Vokoun, and S. Saunders. 2015. *Wisconsin logging sector: status and future direction.* University of Wisconsin Extension G4073, Madison, WI. 26 p.

Robbins, K. 1984. *Annosus root rot in eastern conifers*. Forest and disease leaflet 76. USDA Forest Service. 10 p.

Rosenfield, R. N, J. Bielefeldt, D.R. Trexel, and T.C.J. Doolittle. 1998. Breeding distribution and nest-site habitat of Northern Goshawks in Wisconsin. *Journal of Raptor Research* 25:132-135.

Samistraro, G. and P.W. Hart. 2012. From tree cutting to pulping: the impact of storage time on pulp mill economics. *TAPPI* 11(11):43-49.

Scanlon, K. 2008. *Annosum root rot economic analysis interim progress report.* Wisconsin Department of Natural Resources. 5 p.

Scheaffer, R.L., W. Mendenhall III, and R.L. Ott. 2006. *Elementary survey sampling*. 6th ed. Thomson Brooks/Cole, Belmont, CA. 464 p.

Shy, K. 2006. Wisconsin's forestry best management practices for water quality 1995-2005. Wisconsin Department of Natural Resources, Division of Forestry PUB-FR-349.

Shogren, J.F., J. Tschirhart, T. Anderson, A.W. Ando, S.R. Beissinger, D. Brookshire, G.M. Brown, D. Coursey, R. Innes, S.M. Meyer and S. Polasky. 1999. Why economics matters for endangered species protection. *Conserv. Biol.* 13(6):1257-1261.

Simpson, W.T. and J.C. Ward. 1991. Log and lumber storage. P. 219-238 in *Dry kiln operator's manual.* Simpson, W.T. (ed.). U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, WI.

Stuart, G. W. and P. J. Edwards. 2006. Concepts about forests and water. *North. J. Appl. For.* 23(1):11-19.

Todd, K.M. and R.W. Rice. 2005. Factors affecting pulpwood inventory levels in the northeastern United States. *For. Prod. J.* 55(7/8):17-21.

United States Fish and Wildlife Service (USFWS). 2003. *Karner blue butterfly final recovery plan*. Available online at: http://www.fws.gov/midwest/endangered/insects/kbb/kbbRecPlan.html; last accessed December 29, 2015.

United States Fish and Wildlife Service (USFWS). 2015. White nose syndrome (WNS) zone map. Available online at http://www.fws.gov/midwest/endangered/mammals/nleb/pdf/WNSZone.pdf; last accessed December 29, 2015.

United States Fish and Wildlife Service (USFWS). 2016. Northern long-eared bat (*Myotis spetentrionalis)* statust: Threatened with 4(d) rule FWS-R5-ES-2011-0024 Available online at http://www.fws.gov/midwest/endangered/mammals/nleb/pdf/FRnlebFinal4dRule14Jan2016.pdf; last accessed January 29, 2016.

University of Wisconsin-Madison, Wisconsin Department of Natural Resources, and University of Wisconsin-Extension. 2006. *Wisconsin's wood using industry online database*. Available online at www.woodindustry.forest.wisc.edu/; last accessed October 6, 2014.

Wausau and Marathon County Parks, Recreation, and Forestry Department. 2015. *Second advertisement: Fall 2015 timber sale invitation for bids*. Available online at http://www.co.marathon.wi.us/Portals/0/Departments/PKS/Documents/SecondTimberSalePacket.pdf; last accessed October 19, 2015.

Wilson, A.D. 2001. Oak wilt: A potential threat to southern and western oak forests. *J. For.* 99(5):4-11.

Wisconsin Department of Natural Resources [WDNR]. 2005. *Wisconsin's strategy for wildlife species of greatest conservation need*. Madison, WI. Accessed online at: http://dnr.wi.gov/files/PDF/pubs/ER/ER0641.pdf; last accessed January 29, 2015.

Wisconsin Department of Natural Resources [WDNR]. 2007. *Karner blue butterfly HCP management protocol: timber harvesting*. Accessed online at: http://dnr.wi.gov/topic/ForestPlanning/documents/HCPUsersGuideTimber.pdf; last accessed December 29, 2015.

Wisconsin Department of Natural Resources [WDNR]. 2010a. *Wisconsin's forestry best management practices for water quality: Field manual for loggers, landowners, and land managers*. FR-093. 162 pgs.

Wisconsin Department of Natural Resources [WDNR]. 2010b. *Wisconsin forest health protection annual report 2010*. pgs 33-35. Available online at: http://dnr.wi.gov/topic/ForestHealth/documents/AnnualReport2010.pdf; last accessed December 21, 2015).

Wisconsin Department of Natural Resources [WDNR]. 2011. *Wisconsin forest management guidelines*. PUB-FR-226. Available online at http://dnr.wi.gov/topic/forestmanagement/guidelines.html; last accessed January 4, 2016.

Wisconsin Department of Natural Resources [WDNR]. 2013. *A risk-based guide for the fungicide treatment to prevent annosum root rot in Wisconsin.* Available online at http://dnr.wi.gov/topic/foresthealth/documents/AnnosumTreatmentGuide.pdf; last accessed December 29, 2015.

Wisconsin Department of Natural Resources [WDNR]. 2015a. *2015 directory of foresters*. Available online at http://dnr.wi.gov/files/pdf/pubs/fr/FR0021.pdf; last accessed January 13, 2016.

Wisconsin Department of Natural Resources [WDNR]. 2015b. *Oak wilt: guidelines for reducing the risk of introduction and spread.* Available online at http://dnr.wi.gov/topic/ForestHealth/OakWiltGuide.html; last accessed September 28, 2015.

Wisconsin Department of Natural Resources [WDNR].2015c. *Silvicuture and forest aesthetics handbook, 2431.5*. Available online at: http://dnr.wi.gov/topic/forestmanagement/silviculture.html; last accessed December 29, 2015.

Wisconsin Department of Natural Resources [WDNR]. 2015d. *Timber harvest in Wisconsin.* Available online at http://dnr.wi.gov/topic/forestbusinesses/documents/timberharvestwisconsin.pdf; last accessed December 29, 2015.

Wisconsin Department of Natural Resources [WDNR]. 2015e. *Wisconsin's forest products industry*. Available online at http://dnr.wi.gov/topic/forestbusinesses/documents/wisconsinforestproductsindustry.pdf; last accessed October 7, 2015.

Wisconsin Department of Natural Resources [WDNR].2015f. *Wisconsin's managed forest law: A program summary*. PUB-FR-295. Available online at: http://dnr.wi.gov/topic/forestmanagement/documents/pub/fr-295.pdf; last accessed December 29, 2015.

Wisconsin Department of Natural Resources [WDNR]. 2015g. *Season dates and application deadlines: Deer.* Available online at http://dnr.wi.gov/topic/hunt/dates.html; last accessed January 13, 2016.

Wisconsin Department of Natural Resources [WDNR]. 2015f. *Broad Incidental Take Permit and Broad Incidental Take Authorization for Wisconsin Cave Bats Conservation Plan 11-20-2015 [BITP/A]*. Available online at http://dnr.wi.gov/topic/erreview/documents/batconservationplan1-10-11b.pdf; last accessed December 29, 2015.

Wisconsin Department of Transportation. 2015. *Weight restriction program*. Available online at http://wisconsindot.gov/Pages/dmv/com-drv-vehs/mtr-car-trkr/ssnl-wt-rsrctns/default.aspx; last accessed December 29, 2015.

Wolf, A.T., L. Parker, G. Fewless, K. Corio J. Sundance, R. Howe, and H. Gentry. 2008. Impacts of summer versus winter logging on understory vegetation in the Chequamegon-Nicolet National Forest. *For. Ecol. Mgmt.* 254:35-45.

Woodford, J.E. and D. Van Doren. 2013. *Northern goshawk (Accipiter gentilis) species guidance*. Wisconsin Department of Natural Resources Bureau of Natural Heritage Conservation PUB-ER-679. 8p.