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Logger Perceptions of Seasonal Environmental Challenges Facing Timber Operations in the Upper Midwest, USA

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ABSTRACT

Loggers and other natural-resource-dependent workers are impacted by variable environmental conditions. This research shares logger perceptions of the impacts of seasonal environmental factors on their operations, which are important for informing forest management and policy. We conducted in-depth interviews with 17 professional loggers and 15 other forestry stakeholders to assess the challenges faced in forest operations in Wisconsin and Michigan's Upper Peninsula. We analyzed interviews and documents to create one representative seasonal calendar, which shows the multiple, overlapping factors affecting timber operations. Many loggers identified impacts from seasonal variability and restrictions related to transportation, environmental conditions, and recreation. Seasonal environmental challenges are intertwined with and inseparable from economic challenges. Spring break-up used to be the time for rest, but increasingly, loggers do not stop working because of financial pressures to continue logging. Understanding the seasonal dynamics of timber operations can inform forest policies and climate change adaptation strategies.

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Climate change adaptation; loggers; qualitative research; seasonal calendar; seasonality; timber industry

Logging operations are essential for forest management and wood products manufacturing, yet the seasonal environmental factors impacting timber harvest operations are not well understood. Logging, along with other resource-dependent livelihoods like fishing and farming, is inherently interwoven with variable environmental conditions (Smithers and Smit 1997). A seasonal calendar is a useful tool, common in development work, to show the temporal distribution of seasonal phenomena and understand relationships between seasonal issues, livelihood strategies (Holland 2007), and local knowledge and conditions (Retnowati et al. 2014). We developed a seasonal calendar for logging in the upper Midwest of the United States, using qualitative interviews and document analysis, which reveals the multiple social and ecological factors contributing to the seasonality of timber operations.

Logging in the upper Midwest has strong seasonal dynamics affecting forest stand access for harvesting and road access for transporting logs. Timber harvesting and transportation are affected by ground conditions, weather, road conditions, seasonal transportation restrictions, and seasonal environmental restrictions. Winters can be highly profitable since frozen ground allows for easier forest access. Harvests are challenging during spring break-up since

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Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/usnr.

wet soils and roads are unstable. The number of seasonal restrictions on timber operations reflects concerns about soil erosion and compaction, habitat needs for sensitive species, prevention of tree diseases, and road damage from heavy trucks. Seasonality plays a key role in timber operations, yet limited research examines perceptions of logging professionals about forest management decisions and their ability to cope with variable seasonal challenges.

Professional loggers are an understudied population facing environmental and social challenges. Loggers support a multi-billion-dollar timber industry in the upper Midwest and globally, and are the workforce harvesting trees and shaping forest composition (Rickenbach, Steele, and Schira 2005). Loggers face problems in the business environment from increasing stumpage prices, travel distance to harvest and sell, equipment costs, global competition, and regulated practices (Allred, Michler, and Mycroft 2011). Loggers report feeling financially challenged and misunderstood by policymakers and the public (Egan 2002; Allred 2009).

Qualitative research sharing loggers' voices is particularly lacking (Egan 2002). Qualitative approaches are important for providing contextual information on how and why social, economic, and environmental processes are related. This is important for seasonality, since the impacts of seasonal environmental factors on timber harvest depend on livelihood strategies and complex restrictions related to weather, transportation, forest management, and recreation.

Loggers face shifting and increasingly uncertain conditions as environmental conditions change, which may require adaptation in logging activities and forest management (Millar, Stephenson, and Stephens 2007; Food and Agriculture Organization [FAO] 2012). Adaptation to variability and change is defined as response to actual or expected impacts that attempt to reduce harm or exploit beneficial opportunities (Intergovernmental Panel on Climate Change [IPCC] 2007). Adaptive capacity is the ability of an individual, company, or system "to prepare for stresses and changes in advance or adjust or respond to the effects caused by the stresses" (Engle 2011).

Loggers, mills, and forest managers must understand the seasonal dynamics of timber operations to anticipate the impacts of policy and management changes on logging and to prepare for climate change. We add to the existing literature by describing and calendaring the seasonal factors that impact logging operations. We asked: (1) How do loggers perceive the impacts of weather conditions on timber operations? (2) How do other seasonal environmental factors (including transportation, forest pathogen management, and recreation) impact the timing of timber operations, and how do loggers adapt to them? (3) How do seasonal constraints on timber operations fit into the broader socioeconomic context for logging?

Loggers and Logging Firm Characteristics

Loggers harvest trees and rely on access to private and public forest land. Many loggers also transport cut logs to mills, so they need access to forest and paved roads. Loggers typically own their harvesting equipment and transport it to each job. Some also own trucks to transport logs to mills. The dominant logging system in Wisconsin is cut-to-length, in which a harvester fells and processes (cuts to logs and removes limbs) and a forwarder moves the logs to a landing. Cut-to-length is a highly mechanized, capital-intensive system that accounted for 49% of firms and 65% of harvest volume in 2010 (Rickenbach, Vokoun,

and Saunders 2015). Other systems include chainsaw-based (32% of firms, also called hand-cutters), feller-buncher (10% of firms), and multiple systems (9% of firms). Loggers have considerable capital investment in their equipment, ranging from multiple systems (median $610,000) to chainsaw-based firms (median $60,000).

There are two primary business models: (1) Loggers buy stumpage (standing timber) from landowners, cut it, and then market (sell) it to a mill, and/or (2) loggers work on contract with a mill, a management company, or a landowner to harvest timber. Logging firms in Wisconsin reported 74% of their harvest volume on sales they purchased and 26% on contract (Rickenbach and Vokoun 2013). Logging operations often have high annual costs and slim profit margins. Most of the logging firms in Wisconsin and Michigan's Upper Peninsula were owner-operator businesses with no employees, and firms were equally or more likely to use subcontractors than to have employees (Rickenbach and Vokoun 2013).

The timber industry plays an important role in the Northwoods economy. About 1300 logging firms were operating in Wisconsin and Michigan's Upper Peninsula in 2003 (Rickenbach, Steele, and Schira 2005). The recession of the late 2000s took a toll on the industry; total sawmill receipts decreased 22% between 2003 and 2008 (Haugen 2013). The number of loggers and mills has been declining since prime timberlands were depleted in the early twentieth century. The timber industry seeks predictable and plentiful access to timber and roads, and reliable supply at the mills.

Landowners, resource managers, and transportation departments may be concerned about excessive impacts on forests and roads. Many landowners and agencies place seasonal restrictions on forest and road use to limit damage during certain conditions.

Methods

We conducted 32 in-depth, semistructured interviews with 16 active professional loggers, one retired logger, six foresters, four natural resource managers and extension agents, and five other industry stakeholders, from January 2012 through September 2013, to assess the seasonality of challenges faced in forest operations in the Upper Midwest in the United States.

We first interviewed foresters, natural resource managers, and other industry stakeholders to inform the development of our logger interview guide. Key informant loggers were recommended by the Great Lakes Timber Professionals Association (GLTPA), Wisconsin Master Loggers, Wisconsin Department of Natural Resources (WDNR), and county foresters. We identified additional participants through snowball sampling (Miles and Huberman 1994). We interviewed eight loggers at logging sites in northwest Wisconsin, a region with sandy soils desired during spring breakup; six loggers at a Great Lakes Logging and Equipment Expo booth in Escanaba, Michigan; and three others away from logging sites. Recruitment and interviews continued until data reached saturation (Miles and Huberman 1994). Interviews were audio recorded and transcribed.

We conducted in-person, semistructured logger interviews using a blank seasonal calendar to understand the timing of operations and challenges, making each interview unique (Esterberg 2002). After hearing logger-generated responses, the interviewer then prompted about additional themes generated from preliminary interviews with foresters and managers (interview guide question 3). We asked loggers:

1. Tell me about what kind of challenges you face out here.
2. What keeps you out of the woods when you want to be cutting?

3. [Interviewer prompted on items below that were not yet mentioned by the logger.] How do these things affect you?

   a. Weather.
   b. Equipment.
   c. Stumpage prices.
   d. Mill prices.
   e. Market structure.
   f. Stumpage availability.
   g. Interpersonal relationships.
   h. Ground conditions.
   i. Roads and weight restrictions.
   j. Invasive species and diseases.
   k. Certification.
   l. Recreational activities: hunting, snowmobiling, ATV use.
4. Which has the biggest impact on your productivity and profitability?
5. When do these issues affect you?
6. How do you deal with, plan for, or work around each of those?

Themes were prompted by the interviewer when not mentioned initially by the logger; recreation was most commonly prompted (in 11 of 17 logger interviews) indicating it did not come to mind first in discussing challenges, followed by spring break-up (4), forest pathogens (3), rain (2), and transportation (1). Three loggers were asked to describe their work in 2012 and the factors that impacted them, and the interviewer drew a calendar with these activities and the challenges identified; however, this approach was too time-consuming for interviewees, so we created one calendar summarizing interviewee responses.

We integrated interview data, documents, and environmental data to depict seasonal environmental factors in one calendar. A seasonal calendar shows change through seasons and visualizes the overlap of issues (Bosch et al. 2007). The lead author coded the transcripts by hand according to the themes developed from initial forester and manager interviews, along with an "open coding process" for additional themes discussed by loggers (Esterberg 2002). The section headings in the results and factors in the seasonal calendar figure include those environmental phenomena with a seasonal dynamic that loggers discussed as influencing timber operations. Markets, prices, and costs were the most common responses to our question about challenges, but economic factors are only described in this analysis if they related to seasonal environmental dynamics. We included quotations from interviews to illustrate key findings and provide context for influential factors in the seasonal calendar. We sought to depict the complex connections among seasonal environmental factors and socioeconomic conditions. Participant names were excluded to maintain confidentiality.

The loggers varied in demographic and financial characteristics. Of the 16 active professional loggers interviewed, all were white males with 5–60 years of experience. From this group, 13 were from northern Wisconsin, one from eastern-central Wisconsin, and two from Michigan's Upper Peninsula. The primary equipment used was chainsaws (3), harvester only (3), forwarder only (2), harvester and forwarder (5), harvester, forwarder, and hot saw (2), and chipper (1). Five bought their own stumpage, six only cut under contract with either a mill or another logger, four bought their own stumpage and worked on contract, and one was an employee working for another logger.

Documents from the Michigan and Wisconsin departments of transportation (MDOT and WisDOT), WDNR, and Michigan Department of Natural Resources (MDNR) were analyzed for seasonal factors that assist or constrain timber operations. Road weight restrictions in Michigan were compiled from the Spring Weight Restriction Bulletins (MDOT 2015) and Michigan Truck-weight Law (MDOT 2013). Road weight restrictions in Wisconsin were compiled from Frozen Road Declaration, Frozen Road Declaration History, Springtime Posted Roads, Class II Roads, Class II Roads Spring Weight Restrictions History, and the Detailed Explanation of Raw Forest Products Permit (WisDOT 2012; 2014a; 2014b; 2014c; 2014d; 2014e). Documents from WDNR and MDNR provided specifications and dates regarding rutting, annosum root rot, oak wilt, and hunting seasons (WDNR 2010; 2012; 2013a; 2013b; 2013c; 2014). We calculated average monthly precipitation in Wisconsin for 1981–2010.

Results

Interviewees identified factors with strong seasonal dynamics that influenced timber harvesting and transportation (Figure 1), including (1) weather, (2) transportation policy (WisDOT year-round weight restrictions and seasonal programs to adjust the weight limits when appropriate), (3) forest pathogen management (WDNR recommended harvest guidelines to reduce the risk of disease spread, and (4) recreation policy (snowmobile trails and WDNR 9-day gun deer hunting season). Weather and environmental conditions interact with physical conditions in logging sites to affect logging operations. The center of the calendar shows the average monthly precipitation because overall rainfall as well as

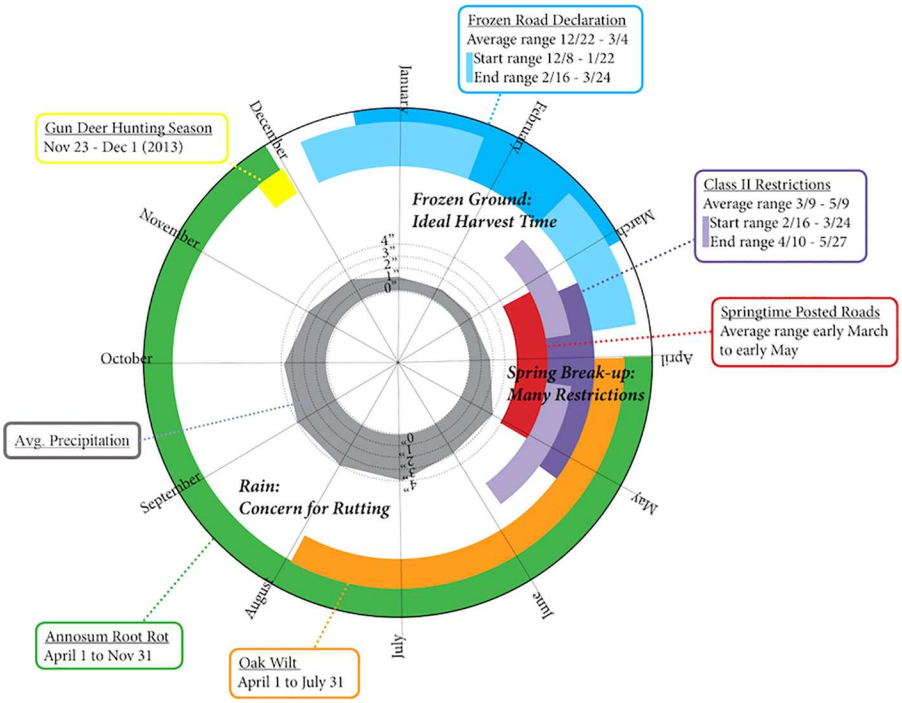

Figure 1. Seasonal factors influencing timber operations in Wisconsin (Michigan's Upper Peninsula dates are similar; see text for differences).

extreme rainfall impacts logging operations. One logger of more than 50 years summarized the complex challenges:

> We've got so many restrictions nowadays on rutting and everything else, if you get a big rain you just have to shut down. If you continually get the rains then you got to move to different ground. That costs you a lot to move, because your equipment's not only not working but you have to spend money on fuel to get your equipment moved to a different spot, so that's also a big factor. Of course, that ties right in with ground conditions. You always have to have some ground that is sandier soil even if the timber's a little bit poorer so you have a place to move when it's wet. You have to always plan for that.

This quotation illustrates the environmental factors facing loggers and demonstrates the interactions among precipitation, operating costs, ground conditions, rutting guidelines, and harvesting decisions. The rest of this section describes logger perspectives on weather impacts and environmental policies that affect the timing of logging operations.

Weather

Weather conditions in the Upper Midwest have seasonal patterns that vary across years, impacting timber operations. Winter was the most productive time of year for the loggers we interviewed, because frozen ground enables access to more timber stands. Most harvesting slowed during spring break-up, the period of freezing and thawing between frozen winter and summer. One logger explained how weather impacts depended on type of equipment:

> Weather is always a factor, more so with hand cutters than with a processor, mechanized. If I had hand cutters, they would be home right now because it's too hot … when it's cold they're gonna be slower to come to work than an equipment operator's gonna be to come to work … rain is gonna send him home quicker … [however] when it's muddy and you're waiting [with a machine] for it to dry out, they [hand cutters] can keep working … during the winter time when the snow gets knee-deep, crotch-deep, mechanized makes life easier. The snow will slow you down maybe a little bit, a very little bit; whereas with the hand cutter, it just kills production. It's a struggle to make a living when the snow gets over knee-deep.

While frozen ground conditions allowed increased logging activity, the transition seasons and rain posed challenges for timber operations.

Frozen ground: Ideal harvest time. Winter and frozen ground conditions meant prime harvest time for the loggers that we interviewed, yet they also explained winter-related challenges. Harvest rates and profitability were both higher during winter, and one logger said he told other loggers to "plan on making your money in 9 months, because from the middle of March until the middle of May you're going to be doing very little." Loggers worked long hours in the winter to capitalize on stable conditions.

Many loggers bought stumpage with a 2-year contract to ensure they could access marginal ground if it didn't freeze hard enough the first year. Marginal ground had poor accessibility or tree growth conditions and was less desirable for loggers. One logger said that winters are "set up to work on marginal ground, where it doesn't dry very good or it's really hard to get into, or you have to freeze a road across a swamp to get it [wood] out." Best management practices, enforced by foresters and landowners, were mandatory on properties with forest certification, including many private and public forestlands. Most loggers we interviewed said they preferred longer contract time frames to have a second harvest season if the timber was inaccessible the first season.

Three winter-related challenges reported by loggers were lack of frozen ground, shorter winters, and extreme cold. First, several loggers thought that in recent winters, the ground was not frozen before the first heavy snowfalls, which meant loggers needed to avoid rutting with their heavy machinery when the ground wasn't frozen solid due to snow insulation. They did not indicate that the snow was deep enough to prevent damage by itself. Second, loggers reported shorter winter periods because "the roads used to freeze down at deer season [November] and you could work until March, now you lose a month off at the beginning and a couple weeks at the end." Third, although less frequently mentioned, was the challenge of extremely cold temperatures. Loggers said that although they liked working in the winter because they could get anywhere, they stayed home when the temperature was −30°F because steel tools could become brittle and more likely to break. Even though loggers were physically comfortable working in the heated cab of their machines, they wouldn't risk damaging their equipment.

With a shortened period of firm or frozen ground ideal for harvesting, the loggers suggested that they lost the opportunity to harvest in sensitive areas, like black spruce in wetlands, which required solid ground to access. Since loggers depended on winter for higher production and to access marginal ground, shortened winter was of particular concern.

Spring break-up: Many restrictions. Spring break-up is the muddy time of year when frozen ground thaws, and traditionally logging operations ceased then due to the risks of getting equipment stuck in the mud and causing environmental damage to the soft ground. Thawing snow and ice made the ground more susceptible to environmental damage from mechanized operations and log transportation. Loggers we interviewed planned their entire year around spring break-up because rutting standards and transportation regulations impacted their ability to work, and they reported increasing financial pressure to continue harvesting throughout the year.

Rutting affects forest productivity and health; impacts from rutting include soil compaction, damaged tree roots and trunks, decreased nutrient uptake, slowed regeneration, increased susceptibility to disease and insect damage, and increased vulnerability to wind throw (WDNR 2010). Measures to control rutting included avoiding operating machinery on soft or wet ground, building roads with proper drainage to prevent rutting, and applying gravel or slash to roads. Certain machines were perceived as causing less damage than others on soft ground. For example, a harvester was thought to not impact the soil as much as a loaded logging truck, because the harvester only dealt with its own weight plus one log. Chainsaw operators within our study were concerned about rutting when transporting product to the mill but not when harvesting by hand.

Some loggers suggested that even if they could operate during spring break-up without causing environmental damage, they would face limited transportation opportunities due to road weight restrictions on public roads. Loggers reported that logging activity slowed or ceased because departments of transportation enforced road weight restrictions and foresters or landowners enforced rutting standards. One interviewee said, "During break-up if we can get in 2 or 3 days a week … if it's a clear-cut sand ground, then you got [restricted travel] postings, you gotta work around them … you plan for that year-round." Road weight restrictions reinforced the fragility that comes with the freeze–thaw cycle, and hauling smaller loads made springtime trucking cost-prohibitive in some cases. Some loggers looked for timber stands along major highways, because they could haul logs with less risk of road

damage. On roads with lower weight limits, loggers could cut and pile the wood to haul after the weight restrictions were lifted.

Loggers reported that they used to stop working during break-up and spend the time fixing equipment and arranging future work; however, many loggers using mechanized systems felt financial pressure to continue working to make payments on their capital investments in equipment. One logger reflected,

> In early 2000, it was a lot easier to take off for spring break-up, and as time went on during that period, the profit margins got thinner and thinner, and costs are going up, and continue to go up, so it got a lot harder to shut down for break-up. A lot of guys are really forced into working during break-up because they can't afford to shut down, because once they shut down, it's really a financial hardship.

In recent years, spring break-up lasted 6–9 weeks (the average length of spring road weight restrictions in Michigan and Wisconsin, respectively), which was considered by those we interviewed as a significant amount of time for a logger to not work.

Loggers coped with the challenges of spring break-up and prepared for the financial hardship by changing work activity, location, timing, or equipment. Many loggers who stopped working in the woods during break-up reported spending the time fixing machinery, looking for timber sales for the next year, and catching up on everything they neglected throughout the year. Loggers were aware of soil moisture and their equipment type when buying stumpage, and most tried to purchase stumpage on sandy soil where moisture was less of a concern to cut in the spring: "Our pine stands are saved for this time of year [March 2013]. It's usually sand, well-drained, dries fast, don't have to worry about it." Some loggers who didn't want to stop working during spring break-up migrated to sand country (especially areas near Spooner and Hayward in northwest Wisconsin), because the soil drained quickly. In some areas, enforcement of road weight limits fluctuated daily when the ground was still frozen. Since chainsaw operators had lower risk of creating ruts than mechanized operators, they continued to work through break-up by working near a stable highway or stockpiling wood to haul after weight restrictions ceased, although they had to skid early in the morning when the ground was frozen.

Rain: Concern for rutting. Precipitation was an important factor for loggers throughout the year, because rain increased the risk of rutting and getting equipment stuck. Many loggers felt the primary option to avoid these risks was to wait for dry ground, despite the financial setback. Too much rain meant loggers couldn't skid, haul wood to the mill, or get paid, because "if you can't haul to get wood through the [mill] gates, you can't get paid." Wet ground combined with the perception of strict regulations and enforcement made it difficult for loggers to conduct business. Loggers we interviewed said foresters could shut down logging operations after rain, even though they know it causes financial hardship for the loggers: "If we get two or three inches of rain, we might be shut down for a couple days, the dollar amount you lose, it's pretty crazy." While some loggers did not harvest or haul after heavy rains because they did not want to damage the roads or create ruts, other loggers worked until they were mandated to stop by foresters.

Many loggers we interviewed acknowledged the importance of bidding on timber stands they could access shortly after rain; they looked for well-drained soil and avoided other soil types if they could. Some interviewees said they would pay more for timber stands on well-drained soil; therefore, threat of rain could lead to higher prices for stumpage on desired soil

types because ideal conditions were in high demand. Many loggers planned for variability, because

> [Weather is] so unpredictable … that's understandable, but that is the biggest factor or biggest challenge I think … I need to have wood moving every day. So when I'm looking at buying my jobs, I look at soil quality. If I know it's not moisture friendly I kind of shy away from it, or if I have a chance of bidding on it, I save it for the wintertime when the ground is froze. But the challenge is to find good workable ground for this time of the year till it freezes again. So I can keep my trucks moving and keep the paychecks coming in.

This speaks to the challenge of finding affordable sites to harvest during the more risky times of year. Many loggers expressed the desire to maintain steady operations and income to meet financial obligations, and they felt the unpredictable nature of weather inhibited their ability to make long-term plans.

Transportation

Logging operations depend on road access for hauling logs from harvest sites to mills, and roads must withstand an extreme range of temperature and moisture throughout the year. Logging operations intensify when pavement is frozen because heavier loads can be transported with minimal risk of damage. Roads are unstable and susceptible to damage during spring break-up. Throughout the year, logging industry transportation is regulated by the WisDOT Raw Forest Products Permit, which "authorizes transport of raw forest products at a gross vehicle weight of 98,000 pounds" with certain vehicle configurations (WisDOT 2012). Three WisDOT programs add caveats to the permits: frozen road declarations, class II roads, and springtime posted roads (Table 1). These programs apply to the state highway system. Local county and town authorities determine their own management strategies and typically align their decisions with WisDOT.

Michigan has a truck weight law that is designed to control axle loads instead of gross vehicle weight (MDOT 2013). This allows for a much higher total weight of trucks, 160,000 pounds, than under the federal weight-law standard. There is no exemption or permitting for logging trucks to exceed axle weights when roads are frozen. During spring break-up, routes designated as "seasonal" are subject to a 25% weight reduction on rigid pavements and a 35% reduction on flexible pavements (MDOT 2015). Roads designated as "all season routes" are exempt from reduction in axle weight during the spring break-up period.

Forest Pathogen Management

Some foresters and policymakers were concerned that logging operations were increasingly influenced by restrictions intended to reduce the spread of disease, including annosum root rot and oak wilt. Annosum root rot, caused by the fungus *Heterobasidion irregulare*, is considered one of the most damaging diseases to conifers in Wisconsin, and its presence was confirmed in 24 counties across the state as of 2013 (Scanlon 2008; WDNR 2013b). The disease was not yet found in the Upper Peninsula of Michigan (MDNR 2014a). Agencies are focused on prevention since the disease is difficult to control once it is present. The WDNR annosum root rot treatment guide helps landowners determine whether chemical treatment should be considered based on distance of the stand from confirmed annosum root rot presence, density of pines, and time of year of harvesting (treat April 1–November

Table 1. WisDOT road weight restriction program for state highways.

Program	Frozen road declarations	Class II roads	Springtime posted roads
State	Wisconsin only	Wisconsin only	Wisconsin and Michigan
Function	Higher weight limits in winter when frozen ground conditions can bear heavier loads; applies to vehicles transporting "peeled or unpeeled forest products cut crosswise not to include woodchips" along with considerations for other industries (WisDOT 2014a).	Lower weight limits in the spring when thawing roads are most vulnerable to damage (WisDOT 2014d).	Protect road sections that are weakened during spring break-up. WisDOT determines on which roads to post signs indicating the allowable weight limits during this period. All postings are for 24-ton maximums (WisDOT 2014c). MDOT applies seasonal weight restriction to all state trunkline highways designated as "seasonal" (MDOT 2013).
Miles of road	"34,192 lane miles minus the Interstate miles" (personal correspondence with WisDOT employee)	"Approximately 1,400 miles (94 segments) of bituminous highways on the Class II list … account for only 12% of the state highways" (WisDOT 2014d)	"Approximately 170 miles (13 segments) of state highways that are posted … account for less than 2% of all state highways" (WisDOT 2014c)
Average start date (range)	December 22 (December 8–January 22) (data from 29 years) (WisDOT 2014b)	March 9 (February 16-March 24) (data from 47 years) (WisDOT 2014e)	Typically second week in March
Average end date (range)	March 4 (February 16–March 24)	May 9 (April 10–May 27)	Typically late April or early May
Average number of days (range)	72 (44–92)	64 (39–83)	43 (28–72); No data on WisDOT website
Average number of weeks (range)	10 (6–13)	9 (5–12)	6 (4–10); No data on WisDOT website
Impact on loggers	Lower transportation costs from fewer trips with heavier loads	Higher transportation costs from more trips with lighter loads	Higher transportation costs from more trips with lighter loads, but fewer road-miles affected

Note. Road miles for county and local roads, which are also important to logging operations, are not included.

30, based on temperature) (WDNR 2013a). Adherence to the guidelines is required on state-owned WDNR lands, and recommended on other forestlands. Most loggers we interviewed harvested outside areas with confirmed annosum root rot presence, and few loggers we interviewed mentioned that it was an issue for operations. Annosum root rot prevention measures may impact logging operations in other areas or in the future, and loggers may plan their harvests to avoid cutting pine stands when the risk of fungal spread is high.

Oak wilt, caused by the fungus *Ceratocystis fagacearum,* is widespread in southern Wisconsin and less common in the northern part of the state (Juzwik, Cummings-Carlson, and Scanlon 2010). Oak wilt management and prevention guidelines suggest two prevention measures to reduce the risk of oak wilt infecting new areas: avoiding cutting from April through July, and minimizing movement of infected firewood or logs (WDNR 2012). The guidelines are determined by presence of oak wilt in the county, distance to a site with oak wilt, region of state, preharvest oak basal area in stand, topography, soil type, and anticipated harvest date. One logger working in the infected area said, "Oak wilt is a big one for us—we can't get started 'til July 15 in any kind of hardwood." However, interviewees who harvested in areas with few oak trees were less concerned about oak wilt restrictions.

Recreation

Interviewees reported that logging activity was moderately impacted by recreational activities, including hunting and snowmobiling. The gun deer hunting season, which runs from the Saturday before Thanksgiving to the Sunday after Thanksgiving in Wisconsin (WDNR 2014) and from November 15 to December 1 in Michigan (MDNR 2014b), can limit logging activity if loggers stop working because of hunters or if they wanted to go hunting themselves. Snowmobile trails have caused tension with timber operations because logging may result in trails being closed, temporarily moved, or signed for snowmobiler safety, though loggers and snowmobilers often communicated well to minimize tension. Some loggers thought recreational forest users, tourists, and seasonal residents held poor opinions of the logging industry, while others felt that relations were not problematic.

Environmental Factors in the Broader Socioeconomic Context

Changes in operations to accommodate seasonal constraints are made at a cost and are impacted by the broader economic and social context of logging operations. Loggers reported dealing with a variety of financial and social challenges, which influenced their ability to respond to the seasonality and variability of the environmental factors. Financially, loggers reported feeling squeezed between stumpage prices and mill prices, and the cost of fuel was always on their mind. Interviewees mentioned economic challenges from mill closures, the dwindling labor force, land parcelization, and inconsistent public perception of the industry. The uncertainty of seasonal weather patterns exacerbated financial and social challenges, making it more difficult for loggers to cope with seasonal constraints.

Discussion

The seasonal calendar reveals patterns in logger access to forests and roads, providing an integrated depiction of seasonal dynamics. Interviews provide insights into how loggers

perceived the impacts of weather and seasonal variation on timber operations. Uncertainties about the timing of seasonal factors hinder planning and increase the financial risk for loggers. The impact is reduced opportunity: lost workdays, reduced harvest, and smaller deliveries to buyers. The combination of socioecological conditions that loggers experience concurrently has created repercussions for logging operations, business, society, and the environment.

We show the overlapping timing—particularly in the spring and summer—of seasonal restrictions, which are key components of sustainable harvesting and transportation rules. We found a growing number of seasonal restrictions to protect roads, recreation, soil, sensitive species, and forest health from emergent diseases. These provisions allow for timber harvesting while protecting resources at sensitive times of the year. Additional restrictions for emerging diseases or newly listed threatened and endangered species such as the northern long-eared bat may also be established in the future. Restrictions are in timber harvest contracts and state guidelines. We documented that seasonal restrictions were a concern for timber industry representatives, and follow-up studies on seasonality then became a research priority for the Great Lakes Timber Professionals Association and the Wisconsin County Forests Association (Wisconsin Council on Forestry 2014). Information on the cumulative effects of seasonal conditions and restrictions should inform policymakers seeking to reduce the risk of environmental damage or conflict with other forest users while ensuring pathways for economic production. For instance, when designing timber sale bid packages, public land managers could assess the seasonal availability of timber, taking into account seasonal restrictions and site conditions near different road classes.

The seasonal calendar documents current conditions and provides a baseline for examining the future effects of climate change, which is very likely to impact the seasonal dynamics of timber harvesting in the Upper Midwest (Janowiak et al. 2014; Pryor et al. 2014). Climate change is expected to affect society's ability to use timber resources through widespread impacts on forest ecosystems and composition globally (Dale et al. 2001; IPCC 2007) and in the Upper Midwest (Wisconsin Initiative on Climate Change Impacts 2011; Handler et al. 2014). Our seasonal calendar depicts several harvest restrictions to prevent the spread of emergent diseases, which are very likely to increase due to climate change (Handler et al. 2014). The reliable winter season for frozen-ground harvesting is declining, which has already led to shifts in species harvested during warmer winters (Rittenhouse and Rissman 2015). Snow is likely to be less frequent but more intense, with a mixed effect on site access (Notaro et al. 2014). Other predicted changes include increased temperatures, more variable precipitation with wetter winters and drier summers, increased damage from extreme weather (Chagnon 2009), increased forest pests, and increased unpredictability (Janowiak et al. 2014). Seasonal dynamics need to be well understood to anticipate potential climate change impacts on the forestry sector.

Simultaneously, loggers face potentially large socioeconomic challenges from globalization, mechanization, demographic shifts, and increasing concern for environmental sustainability (Spittlehouse and Stewart 2003). Loggers are economically vulnerable because they face variable and risky conditions, purchase expensive equipment, and have narrow profit margins. Few new firms are entering the industry to replace the aging firm owners nearing retirement (Rickenbach, Steele, and Schira 2005; Allred 2009; Egan 2009; Rickenbach and Vokoun 2013). Logging operations are pressured to reduce cost by increasing efficiency (Rickenbach and Steele 2005) and invest time in continuing education training (Egan, Hassler, and Grushecky

1997; Kilgore et al. 2007). Loggers face changing landownership and increasing parcelization (Rickenbach and Steele 2006; Allred, Michler, and Mycroft 2011). Predicted future challenges include small woodlot access, changing landowner preferences, global markets, and internal industry dynamics (Rickenbach, Steele, and Schira 2005). Shifting seasonal dynamics are likely to play a small but significant role in the overall economics of logging.

Loggers have adapted practices to reduce the negative impacts of seasonal environmental factors. Adaptations include shifting the harvest timing and location, planning for uncertain conditions, requesting extended contract lengths, making equipment purchase decisions, and lobbying to reduce seasonal restrictions. Resources are available to help forest managers effectively adapt management to environmental variability and change, but fewer efforts have focused on loggers (Spittlehouse 2005; Swanston et al. 2012). Forest management has social dimensions that may limit ability to respond and adapt to risks associated with climate change, including the long time horizon for forest management decisions, potential for individuals to treat events as isolated and underestimate the risk involved, and multiplicity of risk factors (Davidson, Williamson, and Parkins 2003).

To better understand the implications of seasonal environmental challenges in the timber industry, further research is needed. It will be important to develop and sustain measures to improve logger livelihoods while protecting environmental sustainability and an economically viable industry. One avenue for this may be examining the organization of the timber industry and conditions of subcontracting. We focused primarily on the perspectives of loggers, while future study of the seasonality of timber operations could consider focus groups representing industry stakeholders from mills, land management companies, or forest consulting firms to provide additional perspectives on the seasonal challenges facing forest management.

Conclusion

This article presents the first integrated seasonal depiction of factors that impact the timber access, including weather; ground and road conditions; and protections for roads, recreational access, soils, species, habitats, forest pests, and forest diseases. Timber harvests are highly seasonal and variable from year to year, which creates challenges for loggers. Loggers must plan well in advance to bid on and buy stumpage, but they face unpredictable conditions during timber harvest contract periods. Winter is a high-profit and low-impact time of year for timber harvesting, while spring and summer have many restrictions to reduce environmental and road damage, but winters are shrinking and winter conditions are increasingly variable due to climate change (Rittenhouse and Rissman 2015). Policymakers and land managers should be aware of the overlapping seasonal constraints on logging and transportation as they develop new regulations and contracts.

Environmental challenges are intertwined with and inseparable from economic challenges. Loggers have always dealt with unpredictable weather and continue to adapt their practices by considering ground conditions when buying stumpage, planning other work, and adopting new technology. However, loggers' capacity to adapt to increasing environmental change may be limited by high operational costs, low timber prices, and substantial financial investment in equipment. For instance, spring break-up used to be the time for rest, but increasingly, loggers report they cannot stop because of financial pressures, which may raise the risk of environmental damage.

Loggers face the challenge of adapting to environmental changes, while the ever-changing timber industry may require a high level of adaptation by loggers just to stay in business. Seasonal constraints on harvesting due to weather and invasive species are likely to become even more challenging, given climate change projections. Opportunity exists to build adaptive capacity for sustainable timber management through logger training, revisiting the economic role of loggers in production systems, and responsiveness by managers and policymakers. Individual loggers acting alone will not likely overcome the challenges, and it may take a collaborative effort from the logging community, industry, and environmental stakeholders to implement effective strategies for sustainable harvesting.

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References

Allred, S. 2009. Logging firm succession and retention. *Forest Products Journal* 59:31–36. http://www.human-dimensions.org/storage/Logging%20Firm%20Succession%20and%20Retention.pdf

Allred, S., C. Michler, and C. Mycroft. 2011. Midwest logging firm perspectives: Harvesting on increasingly parcelized Forestlands. *International Journal of Forestry Research* 2011:1–8. doi:10.1155/2011/320170

Bosch, O. J. H., C. A. King, J. L. Herbohn, I. W. Russell, and C. S. Smith. 2007. Getting the big picture in natural resource management—Systems thinking as 'method' for scientists, policy makers and other stakeholders. *Systems Research and Behavioral Science* 24:217–32.

Chagnon, S. A. 2009. Temporal changes in extremely damaging storms. *Physical Geography* 30 (1):17–26. doi:10.2747/0272-3646.30.1.17

Dale, V. H., L. A. Joyce, S. McNulty, R. P. Neilson, M. P. Ayres, M. D. Flannigan, P. J. Hanson, L. C. Irland, A. E. Lugo, C. J. Peterson, D. Simberloff, F. J. Swanson, B. J. Stocks, and B. M. Wotton. 2001. Climate change and forest disturbances. *Bioscience* 51:723–34. doi:10.1641/0006-3568(2001)051[0723:ccafd]2.0.co;2

Davidson, D. J., T. B. Williamson, and J. R. Parkins. 2003. Understanding climate change risk and vulnerability in northern forest-based communities. *Canadian Journal of Forest Research* 33:2252–61. doi:10.1139/x03-138

Egan, A. F. 2002. Uniting an independent and isolated workforce: The logger association phenomenon in the United States. *Society & Natural Resources* 15:541–52. doi:10.1080/08941920290069164

Egan, A. F. 2009. Characteristics of New York's logging businesses and logging business owners. *Northern Journal of Applied Forestry* 26 (3):106–10.

Egan, A. F., C. C. Hassler, and S. T. Grushecky. 1997. Logger certification and training: A view from West Virginia's logging community. *Forest Products Journal* 47:46–50.

Engle, N. L. 2011. Adaptive capacity and its assessment. *Global Environmental Change* 21:647–56.

Esterberg, K. G. 2002. *Qualitative methods in social research*. Boston, MA: McGraw-Hill.

Food, and Agriculture Organization. 2012. Forest management and climate change: Stakeholder perceptions. Forests and Climate Change Working Paper 11. Rome, Italy.

Handler, S. D., C. W. Swanston, P. R. Butler, L. A. Brandt, M. K. Janowiak, M. D. Powers, and P. D. Shannon. 2014. Climate change vulnerabilities within the forestry sector for the Midwestern United States. In *Climate change in the Midwest: A synthesis report for the national climate assessment*, ed. J. A. Winkler, J. A. Andresen, J. L. Hatfield, D. Bidwell, and D. Brown, 114–51. Washington, DC: Island Press.

Haugen, D. E. 2013. *Wisconsin timber industry: An assessment of timber product output and use, 2008*. Newtown Square, PA: USDA Forest Service.

Holland, J. 2007. *Participatory tools for micro-level poverty and social impact analysis (seasonal calendar). Tools for institutional, political, and social analysis of policy reform: A sourcebook for development practitioners*. Washington, DC: World Bank. http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTSOCIALDEVELOPMENT/EXTTOPPSISOU/0,,contentMDK:21421096~menuPK:4028954~pagePK:64168445~piPK:64168309~theSitePK:1424003,00.html

Intergovernmental Panel on Climate Change. 2007. *IPCC fourth assessment report: Climate change 2007 (AR4)*. Cambridge, NY: IPCC. https://www.ipcc.ch/publications_and_data/ar4/wg2/en/contents.html

Janowiak, M. K., L. R. Iverson, D. J. Mladenoff, E. Peters, K. R. Wythers, W. Xi, L. A. Brandt, 2014. Forest ecosystem vulnerability assessment and synthesis for Northern Wisconsin and Western Upper Michigan: A report from the Northwoods climate change response framework project. Gen. Tech. Rep. NRS-136, USDA Forest Service, Newtown Square, PA.

Juzwik, J., J. Cummings-Carlson, and K. Scanlon. 2010. Risk analysis and guidelines for harvest activities in Wisconsin Oak Timberlands to minimize Oak Wilt threat. In *Advances and threat assessment and their application to forest and rangeland management*, vol. 1, General Tech., 599–607. Portland, OR: USDA Forest Service Pacific Northwest Research Station. http://www.fs.ed.us/wwetac/publications/pnw_gtr802a.pdf

Kilgore, M. A., J. E. Leahy, J. S. Donnay, C. M. Hibbard, and C. R. Blinn. 2007. Evaluating logger certification attitudes and preferences: A Minnesota case study. *Forest Products Journal* 57:84–90.

Michigan Department of Natural Resources. 2013. Michigan's truck-weight law and truck-user fees. http://www.michigan.gov/documents/mdot/MDOT_013-4-16TruckWeightsMichigan_418609_7.pdf

Michigan Department of Natural Resources. 2014a. Forest health highlights. http://www.midnr.com/Publications/pdfs/ForestsLandWater/ForestHealth/Forest_Health_Highlights_2014.pdf

Michigan Department of Natural Resources. 2014b. Michigan hunting and trapping digest. http://www.michigan.gov/documents/dnr/hunting_and_trapping_digest_461177_7.pdf

Michigan Department of Natural Resources. 2015. Spring weight restriction bulletins. http://mdotcf.state.mi.us/public/alerts/bulletins.cfm?bulletin=spring

Miles, M. B., and A. M. Huberman eds. 1994. *An expanded sourcebook, Qualitative data analysis*, 2nd ed. Thousand Oaks, CA: Sage.

Millar, C. I., N. L. Stephenson, and S. L. Stephens. 2007. Climate change and forests of the future: Managing in the face of uncertainty. *Ecological Applications* 17:2145–51. doi:10.1890/06-1715.1

Notaro, M., D. Lorenz, C. Hoving, and M. Schummer. 2014. Twenty-first-century projections of snowfall and winter severity across Central-Eastern North America. *Journal of Climate* 17:6526–50. doi:10.1175/jcli-d-13-00520.1

Pryor, S. C., C. Scavia, M. Downer, L. Gaden, R. Iverson, J. P. Nordstrom, and G. P. Robertson. 2014. Midwest. In *Climate change impacts in the United States: The third national climate change assessment*, ed. J. M. Melillo, T. C. Richmond, and G. W. Yohe, 418–40. U.S. Global Change Research Program. doi:10.7930/J0J1012N

Retnowati, A., E. Anantasari, M. A. Marfai, and A. Dittmann. 2014. Environmental ethics in local knowledge responding to climate change: An understanding of seasonal traditional calendar pranotomongso and its phenology in Karst Area of GunungKidul, Yogyakarta, Indonesia. *Procedia Environmental Sciences* 20:785–94. doi:10.1016/j.proenv.2014.03.095

Rickenbach, M. G., and T. W. Steele. 2005. Comparing mechanized and non-mechanized logging firms in Wisconsin: Implications for a dynamic ownership and policy environment. *Forest Products Journal* 55 (11):21–26.

Rickenbach, M. G., and T. W. Steele. 2006. Logging firms, nonindustrial private forests, and forest parcelization: Evidence of firm specialization and its impact on sustainable timber supply. *Canadian Journal of Forest Research* 36 (1):186–94. doi:10.1139/X05-238.

Rickenbach, M. G., T. W. Steele, and M. Schira. 2005. *Status of the logging sector in Wisconsin and Michigan's Upper Peninsula 2003*. Madison, WI: Board of Regents of the University of Wisconsin System, University of Wisconsin Extension.

Rickenbach, M. G., and M. Vokoun. 2013. Wisconsin logger study results: Comparing then and now. http://fyi.uwex.edu/notcountingtrees/2013/04/16/blogging-logging-1-introduction-to-2011-logging-sector-survey-findings (accessed September 13, 2015).

Rickenbach, M. G., M. Vokoun, and S. Saunders. 2015. *Wisconsin logging sector: Status and future direction.* Madison, WI: Board of Regents of the University of Wisconsin System, University of Wisconsin Extension.

Rittenhouse, C. D., and A. R. Rissman. 2015. Changes in winter conditions impact forest management in north temperate forests. *Journal of Environmental Management* 149:157–67. doi:10.1016/j.jenvman.2014.10.010

Scanlon, K. 2008. Annosum root rot economic analysis interim progress report. Wisconsin Forest Health Annual Report 2008. Madison, WI: Wisconsin Department of Natural Resources.

Smithers, J., and B. Smit. 1997. Human adaptation to climatic variability and change. *Global Environmental Change* 7:129–46. doi:10.1016/s0959-3780(97)00003-4

Spittlehouse, D. L. 2005. Integrating climate change adaptation into forest management. *Forestry Chronicle* 81:691–95. doi:10.5558/tfc81691-5

Spittlehouse, D. L., and R. B. Stewart. 2003. Adaptation to climate change in forest management. *BC Journal of Ecosystems and Management* 4:1–11.

Swanston, C., M. Janowiak, P. Butler, L. Parker, M. St. Pierre, and L. Brandt. 2012. *Forest adaptation resources: Climate change tools and approaches for land managers.* Newtown Square, PA: USDA Forest Service.

Wisconsin Council on Forestry. 2014. Wisconsin forest practices study: Request for proposals 2.0. Accessed November 5, 2014. http://www.wisconsinforestry.org/files/practicesStudy/RequestForProposals2.pdf

Wisconsin Department of Natural Resources. 2010. Wisconsin's forestry best management practices for water quality/field manual for loggers, landowners, and land managers. http://dnr.wi.gov/topic/forestmanagement/documents/pub/FR-093.pdf

Wisconsin Department of Natural Resources. 2012. Oak wilt guide. Accessed August 3, 2015. http://dnr.wi.gov/topic/foresthealth/OakWiltGuide.html

Wisconsin Department of Natural Resources. 2013a. A risk-based guide for the fungicide treatment to prevent Annosum root rot in Wisconsin. Accessed June 10, 2014. http://dnr.wi.gov/topic/foresthealth/documents/AnnosumTreatmentGuide_Proposed.pdf

Wisconsin Department of Natural Resources. 2013b. Annosum root rot. Accessed June 10, 2014. http://dnr.wi.gov/topic/foresthealth/annosumrootrot.html

Wisconsin Department of Natural Resources. 2013c. Oak wilt: Guidelines for reducing the risk of introduction and spread, vol. 2007. Accessed June 10, 2014. http://dnr.wi.gov/topic/ForestHealth/documents/OakWiltGuidelines.pdfWDNR

Wisconsin Department of Natural Resources. 2014. 2014 Wisconsin hunting and trapping seasons (Pub WM-153–2014). Accessed June 10, 2014. dnr.wi.gov/files/PDF/pubs/wm/WM0153.pdf

Wisconsin Department of Transportation. 2012. Detailed explanation of s348.27(9 m)4. Raw forest products permit. s348.27(9 m)4. Vol. 27. US. Accessed June 10, 2014. http://www.dot.wisconsin.gov/travel/truck/frozenroad.htm

Wisconsin Department of Transportation. 2014a. Class II roads. Accessed June 10, 2014. http://www.dot.wisconsin.gov/travel/truck/class2roads.htm

Wisconsin Department of Transportation. 2014b. Class II roads spring weight restrictions history. Accessed June 10, 2014. http://wisconsindot.gov/Documents/dmv/com-drv-vehs/mtr-car-trkr/ssnl-wt-rsrctns/class2history.pdf

Wisconsin Department of Transportation. 2014c. Frozen road declaration. Accessed June 10, 2014. http://wisconsindot.gov/Pages/dmv/com-drv-vehs/mtr-car-trkr/ssnl-wt-rsrctns/frozenroad.aspx

Wisconsin Department of Transportation. 2014d. Frozen road declaration history. Accessed September 3, 2015. http://wisconsindot.gov/Documents/dmv/com-drv-vehs/mtr-car-trkr/ssnl-wt-rsrctns/frozenroadhistory.pdf

Wisconsin Department of Transportation. 2014e. Springtime posted roads. Accessed June 10, 2014. http://wisconsindot.gov/Pages/dmv/com-drv-vehs/mtr-car-trkr/ssnl-wt-rsrctns/postedroads.aspx

Wisconsin Initiative on Climate Change Impacts. 2011. Wisconsin's changing climate: Impacts and adaptation. Madison, WI. http://www.wicci.wisc.edu/publications.php