Chapter 33

Jack Pine Cover Type

6/1/2022
Last Full Revision: 02/09/2016
Note- this chapter has not been fully revised since the restructuring of the Wisconsin Silviculture Guide, therefore some subject areas may be missing in the current version of this chapter

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1 TYPE DESCRIPTION

1.1 Stand Composition and Associated Species

Stand Composition
Jack pine (*Pinus banksiana*) comprises 50% or more of the basal area in poletimber or sawtimber stands, or 50% or more of the stems in seedling and sapling stands.

Associated Species
Jack pine frequently occurs in dense, even-aged stands that originate from major disturbances, such as fire or logging. In stands dominated by jack pine, the most common associates are oak (*Quercus spp.*), red pine (*Pinus resinosa*), white pine (*Pinus strobus*), aspen (*Populus spp.*), and white birch (*Betula papyrifera*). Occasional associates include red maple (*Acer rubrum*), black cherry (*Prunus serotina*), balsam fir (*Abies balsamea*), and white spruce (*Picea glauca*).

1.2 Silvical Characteristics

Note: The primary source for the following descriptions and tabular summary is from Silvics of North America – Jack Pine (94). Visit Silvics of North America website for additional information:
https://www.srs.fs.usda.gov/pubs/misc/ag_654/volume_1/pinus/banksiana.htm

Flowering and Fruiting
Jack pine is a monoecious species; meaning an individual has both male and female strobili (cones). The female (ovulate) cones are usually borne on primary and secondary branches in the upper tree crown. Male (staminate) cones are usually borne on the lower crown. Jack pine trees, particularly under good early growing conditions, begin to flower at a younger age than most other pine species. In the Lakes States, flowers become visible in mid to late May and pollination occurs shortly thereafter. Fertilization occurs about 13 months after pollination when the female cone is approaching its maximum size of 1 to 2 inches. Jack pine is normally a wind-pollinated, cross-fertilizing species, but natural self-fertilization can occur (rarely more than 25 percent). Under natural conditions survival of self-fertilized seedlings is severely reduced by natural selection, as a result of inbreeding depression.

Once cone production in jack pine begins (typically 5-10 years), it is fairly regular and increases until crown competition becomes a factor. Jack pine cones take two growing seasons to mature. Cones are approximately ¼ inch long by the end of the first season and reach a mature size of 1 to 2 inches by the end of the second growing season. Moisture content of cones and viability of seed decrease as cones age, with cone color changing from green to brown to gray. Some cones fall to the ground each year but some cones remain on the tree for 20 years or longer.

Based on a cone study of Lake States jack pine provenances, the best indicators of cone and seed ripeness are cone color; 75 percent brown and insides of the cone scales, reddish brown; seed coat color, dark brown or black; and cone moisture content, less than 45 percent of fresh weight. These indicators of cone and seed ripeness coincide with the beginning of cone harvesting by squirrels in September (19).

Over much of its natural range jack pine bears predominantly serotinous cones, but along the southern range limit cones are sometimes non-serotinous. A survey of serotiny in jack pine across Wisconsin's Northwest Sands showed the highest levels of serotiny in the northeast portion and lowest in the southwest portion. A possible explanation for the gradient in serotiny levels may be the difference in forest density and corresponding fire regimes across this landscape. Historical vegetation patterns indicate forest density to have been highest in the northeast and lowest in the southwest portions. The savanna-type landscape of the southwest Pine Barrens experienced frequent, non-lethal surface fires that may have favored trees with non-serotinous cones. High density tree cover in the northeast portion of the Pine Barrens would have allowed for stand replacing crown fires that may have favored trees with serotinous cones (87).

Serotinous cones may remain closed for 10 to 25 years until they are exposed to fire or high temperatures near the ground after wind breakage or logging. Some serotinous cones open during hot, dry weather (temperatures of at least 80°F). Up to 50 percent of cones may open on the sun-exposed portion of the crown. The resin of serotinous cones melts at temperatures of 122-140° F or higher, but it is likely that the bonding resin softens at lower temperatures in the non-serotinous types. The mechanism of cone opening in both serotinous and non-serotinous cones is hygroscopic. Once the bonding material of the cone scales is broken, the quantity of water in the scales is the limiting factor in scale movement and flexing outward under drying condition.

Seed Production and Dissemination

In naturally regenerated stands, seed production begins at 5 to 10 years in open-grown stands and at 10 to 25 years in closed stands. Best seed production is from trees between 40 and 50 years old. A well-stocked stand can produce 13 pounds of seed per acre with seed numbers averaging 131,000 seeds per pound. Good seed years occur every 3 to 4 years with light crops in most intervening years. Crop failures are rare.

Seeds retained in cones maintain high viability for at least 5 years and sometimes for more than 15 years. However, because viability after 5 to 10 years may be significantly reduced, only cones 6 years old or less should be collected. Cone and seed crops in jack pine may be reduced by numerous agents, including insects and rainy weather at time of pollination.

In the Lake States, where non-serotinous or partially serotinous cones may be present, seed can be disseminated during any season. The winged seeds are the smallest of the native pines and are dispersed by gravity and wind. The range of seed dispersal is about two tree-heights (110-130 feet). Birds and rodents can consume up to 75 percent of dispersed seed.

Seed yields per cone range from about 15 to 75. Strongly curved cones yield less seed than straight ones. Well-stocked, mature stands in the Lake States dispersed an annual average of 2,700 to 10,500 seeds per acre over 5 years, but much of the total crop remained in the unopened cones. Seed viability is not markedly affected by heating, unless the cone ignites, which kills the seed. Crown torching does not ignite cones because the high temperatures are unlikely to last more than 3 minutes.

In cones exposed to fire, seeds are uninjured by temperatures that do not cause actual cone ignition (e.g., 60 sec at 700°F, 30 sec at 900°F, 2 sec at 1200°F). Seed can be shed for 3 years after a fire event.

Seedling Development

Light, moisture, air temperature and seedbed conditions influence germination and seedling survival. Optimum conditions for jack pine seedling establishment and survival are provided by exposed mineral soil and burned seedbeds where competition from other vegetation is not severe, the water table is high (within 6 feet), and there is light partial shade.

Seeds germinate within 15 to 60 days when conditions are favorable. Germination rates are reduced if seed is exposed to direct sunlight more than four hours per day or in full shade conditions. The shade cast by slash and snags on burned-over or cut-over areas reduces surface temperatures and drying, contributing substantially to the good germination often observed on such areas. Jack pine seedlings are most abundant in the understory when light intensity is 11 to 30 percent of full sunlight, but height growth is greatest in light intensities of 52 percent or more.

Highest germination and seedling survival rates are observed for seeds that fall in April, May, June, and November. Numerous factors hinder seedling survival: drought, high soil surface temperatures, vegetative competition, prolonged flooding, insects, diseases, deer browse, ice damage, and nipping and girdling by snowshoe hares.

Under forest conditions, seedling growth is slow in the first 3 years but increases rapidly beginning in the fourth and fifth years. During the first season the root system penetrates to a depth of 5 to 10 inches. By the end of the second season, on typical sandy soils, seedlings are 3 to 4 inches tall, and roots are 11 to 13 inches deep with a lateral spread of 18 to 24 inches. By the fourth year, wild seedlings are usually 1 to 3 feet in height. Early growth of 2-0 seedlings in plantations is more rapid, amounting to 12 to 18 inches per year on medium quality sites.

Although jack pine seeds usually germinate following fire, most of the seedlings die unless the organic matter left on the soil is less than 0.5 inch thick. Most germination occurs the first and second season following fire, with most mortality between the first and second growing season. Unless conditions for germination and early survival are favorable, good regeneration does not necessarily follow burns.

Growth and Development

In well-stocked stands, jack pine is short to medium tall, slender, with a narrow open crown covering 30 to 45 percent of stem. In open growth, it tends to be stocky, with poor form and a wide spreading crown with persistent branches, often to the ground. Overstocked stands produce weak, spindly stems that are susceptible to breakage by wind, ice, and snow. Normally, mature trees are 55 to 65 feet tall and 8 to 10 inches DBH, although some trees have attained greater than 100 feet in height and 25 inches DBH.

During the first 20 years, jack pine is one of the fastest growing conifers, being second only to tamarack. Seedlings reach breast height in 5 to 8 years. On average sites, growth averages about one foot a year to 50 years of age. Annual height growth on medium sites averages from 13 inches at age 30 to 9 inches at age 50. At age 80 years, annual height growth is only 5 inches. On the best sites stands begin to decline in growth and vigor after 80 to 100 years; on poor sites after 60 years. Vigorous trees 185 years old have been found in northeastern Minnesota. Most older jack pine stands in the Lake States were established following fires.

Reaction to Competition

Jack pine is one of the most shade-intolerant trees in its native range. It is ranked as less tolerant than red pine and is slightly more tolerant than aspen, birch, and tamarack. Jack pine may be more tolerant in the seedling stage and often requires some shade on dry sites to reduce surface temperatures and evapotranspiration. Soon after seedlings are established, however, they should receive full sunlight to assure survival. Overall, jack pine can be classed as intolerant of shade.

Overstocked jack pine seedling and sapling stands with 2,000 or more trees per acre may be thinned to improve growth and development. Otherwise, such stands may stagnate because natural thinning in jack pine stands is slow except on the best sites. Planting, direct seeding, and precommercial thinning should have a goal of 600 to 1,200 trees per acre (plantations 400-1200).

Jack pine is a pioneer species on burns or exposed sandy sites. In the absence of fire or other disturbances, jack pine is succeeded by more tolerant species, but on the poorest, driest sites it may persist and form a localized climax community.

Damaging Agents

Jack pine is subject to many agents that cause damage or mortality. Young jack pines are especially susceptible to early spring fires. Severe drought may kill many seedlings, particularly on coarse soils. High populations of white-tailed deer can kill young jack pines up to 7 feet tall, retard total height growth to half its potential, and deform most trees so they have little future value for timber products. Snowshoe hares can severely damage jack pine reproduction, particularly in dense stands of trees. Meadow voles cause occasional damage and mortality by gnawing the bark off main stems and lower branches. Porcupines can cause extensive damage in older stands. Jack pine budworm can be a severe defoliator, with outbreaks occurring approximately every 10 years. Wind throw is not a serious problem in jack pine stands except on shallow soils or when more than one-third of the stand basal area is removed in thinnings. Stem breakage from wind, ice, and snow is more common.

Disease can impact both survival and growth of jack pine. Diplodia (Diplodia pinea) and Sirococcus shoot blight (Serococcus conigenus) can cause significant losses in natural and artificial regeneration. Rust fungi, such as pine-oak gall rust (Cronartium quercum), can result in morality when galls form on the main stem.

Cone and seed production can be decreased by numerous factors. Seed and cone insects may limit seed production. Red squirrels and other rodents destroy cones and consume seeds.

Birds may be important consumers of jack pine seeds that fall to the ground or are directly sown. See Forest Health Guidelines section for more detailed information on jack pine damaging agents.

Table 33.1. Summary of selected silvical characteristics

Jack pine (*Pinus banksiana*)	
Flowers	Monoecious spp; mostly wind-pollinated and cross-fertilizing; some natural selfing occurs; pollination occurs mid-May to early June
Fruit	Cones 1 to 2 inches at maturity; 2 years to mature; color changes from green to brown to gray as cones age; varying degrees of serotiny
Seed	Trees can produce seeds early (5 to 10 years) in open grown stands; in closed stands seeds are produced at 10-25 years; good seed crops occur every 3 to 4 years; fully stocked stands can produce 13 pounds of seed per acre with 131,000 seeds per pound; seed yields per cone range from 15 to 75; crop failures are rare; seeds can remain viable in the canopy for many years
Seedlings	Optimum conditions for seedling establishment and survival are provided by exposed mineral soil and burned seedbeds where competition from other vegetation is not severe, the water table is high (within 6 feet), and there is light partial shade. Seeds germinate within 15 to 60 days when conditions are favorable; potential for delayed germination in first two years after seed sown
Growth	Fast growing conifer during the first 20 years. Seedlings reach breast height in 5 to 8 years. On the best sites, stands begin to break down after 80 to 100 years; after 60 years on poor sites.
Tolerance	Shade-intolerant, although in the seedling stage often requires some shade on dry sites to reduce surface temperatures and evapotranspiration. Soon after seedlings are established, however, they should receive full sunlight to assure survival.
Damaging agents	Birds, rodents, deer, snowshoes hares, porcupines, wind, fire, drought, ice, snow, insects and disease.

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

Management objectives should be identified in accordance with landowner goals and within a sustainable forest management framework, which gives consideration to a variety of goals and objectives within the local and regional landscape. The silvicultural systems described herein are designed to promote the optimum quality and quantity of timber products. These

silvicultural systems may be modified to satisfy other management objectives, but vigor, growth, and stem quality could potentially be reduced.

3 LANDSCAPE, SITE, AND STAND MANAGEMENT CONSIDERATIONS

3.1 Landscape Considerations

Jack pine requires disturbance to regenerate and is found in areas that historically experienced frequent and extensive fires, most notably the Pine Barrens and Northern Dry Forest natural communities that were once widespread in Wisconsin's sand-dominated ecological landscapes. Numerous factors including fire suppression, natural succession, land-use changes, ownership patterns, and economic considerations have led to major declines in jack pine dominance and shifts in in the distribution of these natural communities. Pine Barrens in particular are now geographically restricted and considered globally imperiled (128), with the best remaining examples located in the upper Midwest states of Wisconsin, Michigan, and Minnesota.

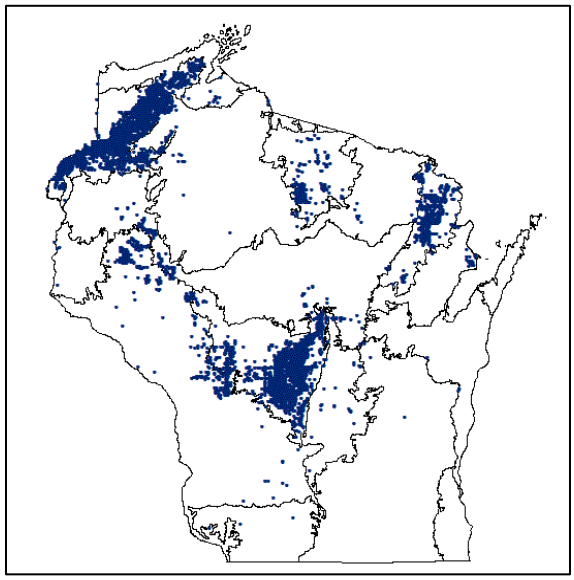


Figure 33.1. Location of jack pine "witness trees" documented during GLO Surveys (from the WDNR GIS coverage Pre-European Settlement Vegetation Database of Wisconsin: Differentiated Section and Quarter Section Corners prepared by the University of Wisconsin – Madison Forest Landscape Ecology Lab).

3.1.1 Historical Context

Jack pine was a major cover type at the time of Euro-American settlement, particularly in the Northwest Sands ecological landscape where "jack pine, scrub oak, and Barrens" made up almost two-thirds of the landscape (32). It was also a major type in the Northeast Sands and the Central Sand Plains with smaller amounts scattered throughout various other landscapes. Figure 33.1 illustrates the locations where jack pine "witness trees" were documented during the General Land Office surveys of the mid-1800s (106).

Relative Importance Value (RIV) is a metric that combines relative basal area and relative density to determine the "importance" of a particular species relative to others in a given area (43). The RIV of jack pine in the Northwest Sands was over 30% at the time of General Land Office surveys in the mid-1880s[1]. Its RIV in the Northwest Sands now, based on 2013 FIA data, is less than half of that amount (Figure 33.2). The RIV decrease is less pronounced in

[1]*Tree data from the General Land Office surveys are from a particular point in time and can be biased for a number of reasons, including due to limitations in the data collection methods. However, as the only statewide source for pre-Euro-American settlement vegetation data, they can be useful for exploring vegetation patterns at large scales, such as ecological landscapes. These data are used here to better understand the ecological capabilities of these areas and not to imply that conditions should be returned to any particular point in Wisconsin's history.*

the Central Sand Plains, but many areas there have also been converted to other forest types and land uses.

In more recent decades, jack pine acreage has been consistently declining in Wisconsin since 1983 based on FIA data (see Figure 33.10), and this change has been concurrent with an increase in red pine (121). Between 2004 and 2014 it is estimated that roughly 40,000 acres of jack pine were converted to red pine in Wisconsin (64).

Disturbance Regime

Fire was historically the primary disturbance throughout the jack pine range in Wisconsin. Crown fires were historically frequent in the Great Lakes with a rotation period of 50-70 years (36). However, fire return intervals and intensities varied across sites creating a diversity of landscape patterns and stand conditions (84). There was likely also a very wide range of fire sizes ranging from 1000 ha to 180,000 ha (36).

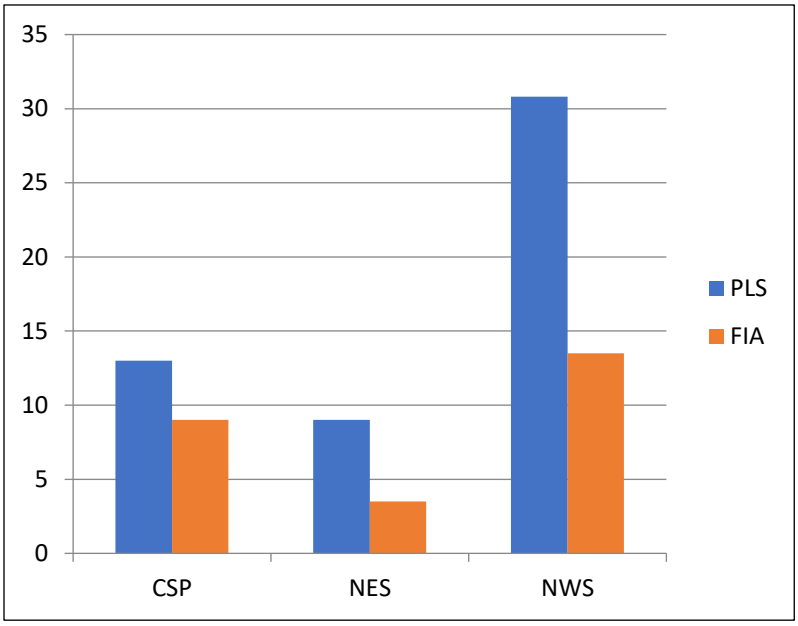


Figure 33.2. Relative importance values from the witness tree data collected in the mid-1800s (PLS) and 2013 Forest Inventory Analysis (FIA) data. The amount shown is the importance of jack pine relative to other tree species during the two time periods for the Central Sand Plains (CSP), Northeast Sands (NES), and Northwest Sands (NWS) ecological landscapes.

The fires were important not only for jack pine regeneration but developing a varied landscape with conditions ranging from dense, mature jack pine to large expanses of treeless or near treeless habitat. For example, at least three distinct subregions were defined in the Northwest Sands that exhibited different levels of fire frequency and intensity (86). Fire suppression efforts formally began in the Northwest Sands in the 1920s, but large areas were still burning as late as the 1930s (85).

The 2013 Germann Road Fire, covering over 7,000 acres, was Wisconsin's largest forest fire in recent years. An earlier fire, the 2005 Cottonville Fire, covered 3,400 acres in the Central Sand Plains. Several fires this size and larger previously occurred in the 1970s and 1980s (85). These events are reminders of the disturbance history of these sand-dominated ecological landscapes, as well as the potential for large fires to occur when an ignition source combines with extreme weather, dry soils, and abundant fuel.

Jack pine budworm, a native needle-feeding caterpillar, can also cause large-scale mortality of mature jack pine, especially during periods of drought (see "Forest Health Guidelines" section).

Historically, large fires would have followed major budworm outbreaks. Huge budworm outbreaks have occurred in the past in Wisconsin when large acreages of jack pine shared the same or similar age classes. An outbreak in 1992 and 1993 resulted in defoliation in 90% of the jack pine forests in the Northwest Sands, and salvage harvests occurred on 27% of the mature forest in the landscape at that time (74, 85).

Salvage harvests and other clearcuts differ from fires in many ways, including the size and shape of the remaining patches, as well as the resulting structure and species composition. Wildfires often result in a patchy, discontinuous landscape with burned and unburned “legacy” structures (25, 48). These structures change light conditions and provide nesting and foraging habitat for certain species. For example, some of the larger snags following a fire provide foraging opportunities for black-backed Woodpecker, a WI Special Concern species (68), especially recently dead trees (69). Fire also makes nutrients available to plants that were bound in organic matter.

Figure 33.3. Photos of the Germann Road Fire of 2013 by (top) Colin Nowaczyk, WDNR and (bottom) Phil Miller, WDNR.

Role in Pine Barrens

Pine Barrens once covered seven percent of Wisconsin’s landscape (116) but are now quite rare. The Pine Barrens community is now ranked as “G2” by NatureServe, the umbrella organization for an international group of Heritage programs including the Wisconsin Natural Heritage Inventory (128). This rank indicates that they are globally imperiled because of rarity.

Pine Barrens is an open community type with trees occurring in low density and either scattered individually or in groups. Prior to Euro-American settlement, there was also a “pine savanna” Barrens type that included large-diameter scattered red pine, but these areas are considered to have since been eliminated (131) (Figure 33.4).

Much of the original Pine Barrens acreage has succeeded to forest or has been converted to other land uses. Of the remnants, many are too small to ensure viability of species that require Barrens habitat (116). However, certain high-quality remnants have been kept open through intensive efforts and connecting and expanding these has been identified as a major conservation priority. This is especially important since there are area-sensitive species associated with Barrens communities such as sharp-tailed grouse (124) that require very large open patches.

There can be major benefits to maintaining open areas within working forest landscapes. Open patches could be located in areas with rare plants and/or floristic diversity, and even small openings placed in these areas can have ecological benefits. These habitats could be incorporated into planning efforts on stands, properties, or regions. Although small patches can provide habitat for rare plants and certain animals, other species are area-sensitive and need much larger openings or very young forest. For example, Kirtland's warbler has been found in patches of 75-100 acres or more of young jack pine, and sharp-tailed grouse need even larger areas (38, 103). However, managing large patches is typically only possible on public lands or large, industrial forest landholdings.

Figure 33.4. Red pine savanna, circa 1890, Bayfield County. Note the individual standing next to the tree in the left side of the image illustrating tree size. From St. Croix Trail Country: Recollections of Wisconsin by William Gray Purcell (University of Minnesota Press, 1967). Copyright 1967 by the University of Minnesota. Used by permission.

Ideally, jack pine stands could be managed as a "shifting mosaic" that would benefit a number of species while allowing for timber management as a primary objective. The pre-Euro-American settlement Pine Barrens included frequent large openings that would have shifted locations over time (84). Figure 33.5 (122) shows an idealized, hypothetical example of how an area could be managed in a similar way through planning. The jack pine stands are harvested on a rotating schedule, so each stand periodically provides an early seral stage "temporary Barrens" connected to the core Barrens unit. Thus, an area with very low tree density is always available for species requiring open habitats. This would also provide habitat for species using young and older jack pine at all times. Shifting clearcuts in this manner would provide very little savanna structure since that would require higher numbers of trees to be retained than a typical clearcut harvest. However, clearcuts can provide some of the open habitat for Barrens species that would otherwise be lost from many areas (40).

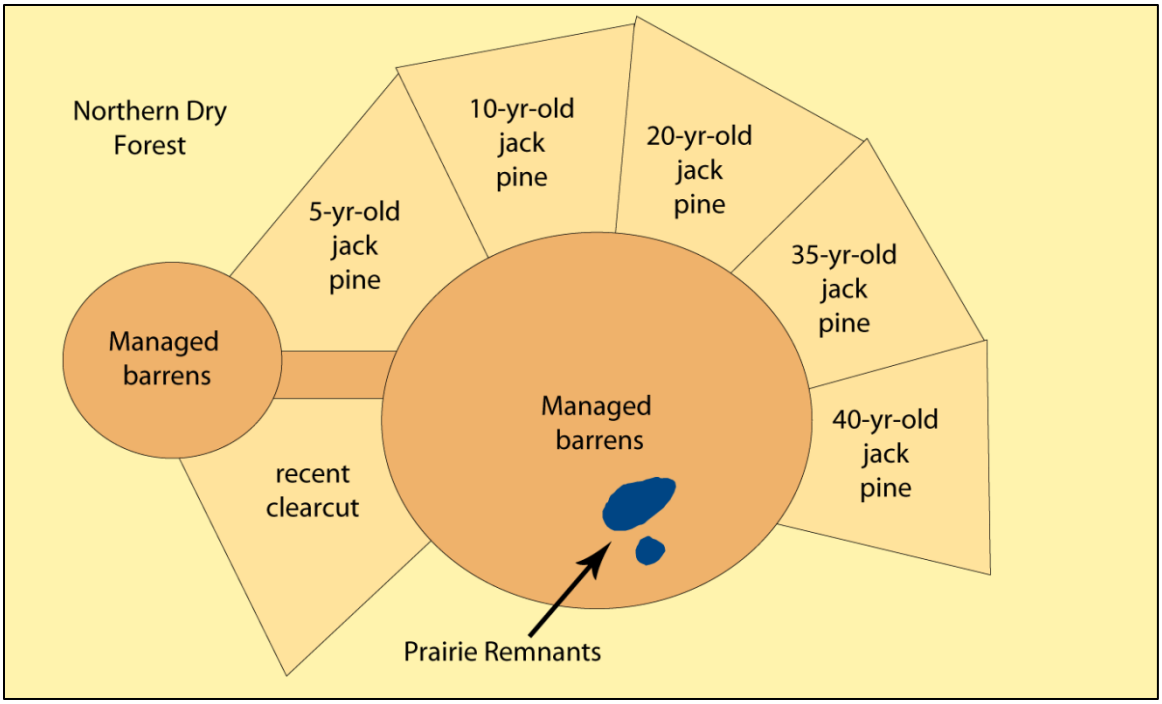


Figure 33.5. Figure adapted from the Ecological Landscapes of Wisconsin, Chapter 1: Principles of Ecosystem and Landscape-Scale Management

3.1.2 Current Context

Jack pine is found mostly in three states (Wisconsin, Minnesota, and Michigan), as well as large areas of Canada. Within Wisconsin, jack pine is more localized than many other tree species. Over 90% of Wisconsin's jack pine acreage is found in five ecological landscapes with large areas of sandy soils. Nearly two-thirds of the acreage is in the Central Sand Plains and Northwest Sands ecological landscapes.

The ecological landscapes with the greatest acreages in jack pine are Central Sand Plains, Northwest Sands, Western Coulees and Ridges, Northeast Sands, and Northern Highlands (Figure 33.6). These are generally the same landscapes where jack pine was dominant historically, but its abundance is reduced, and it continues to decline for a variety of reasons. Modern fire suppression has clearly resulted in a natural conversion to other forest cover types. In addition, land use changes and the decision to plant other species, such as red pine have also reduced jack pine acreage in many cases.

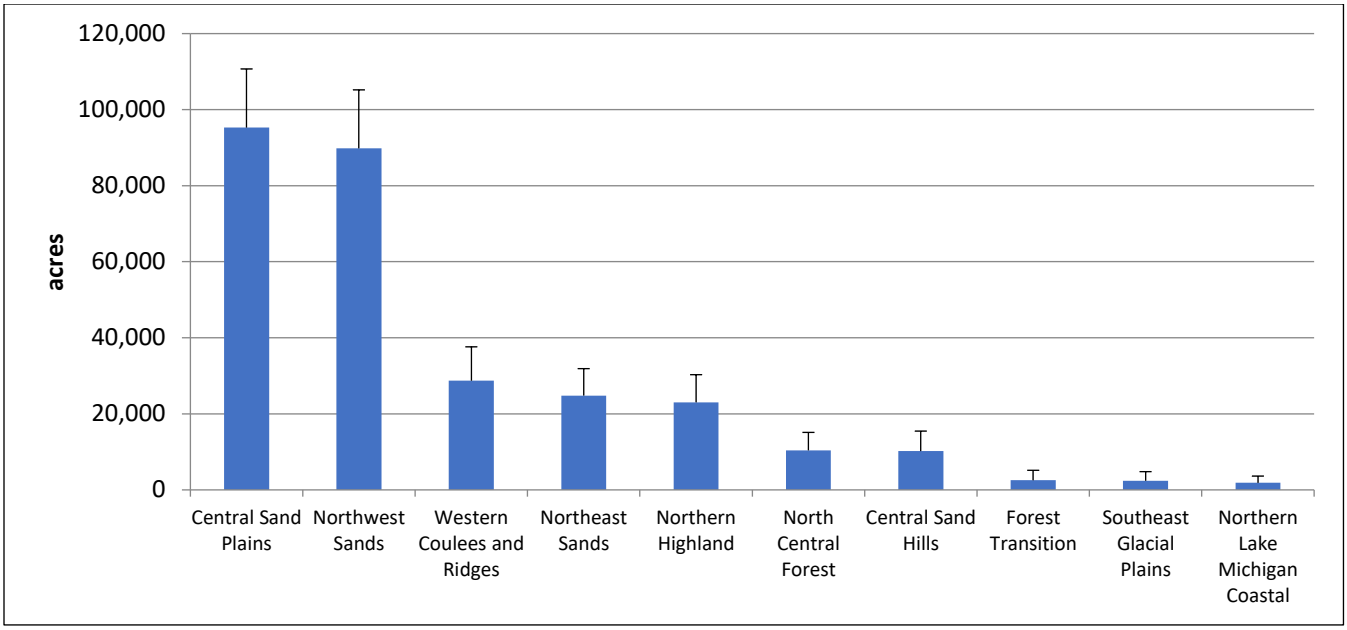


Figure 33.6. Acres (with standard errors) of jack pine by Ecological Landscape in 2013. Data are from the U.S. Forest Service Forest Inventory and Analysis (64).

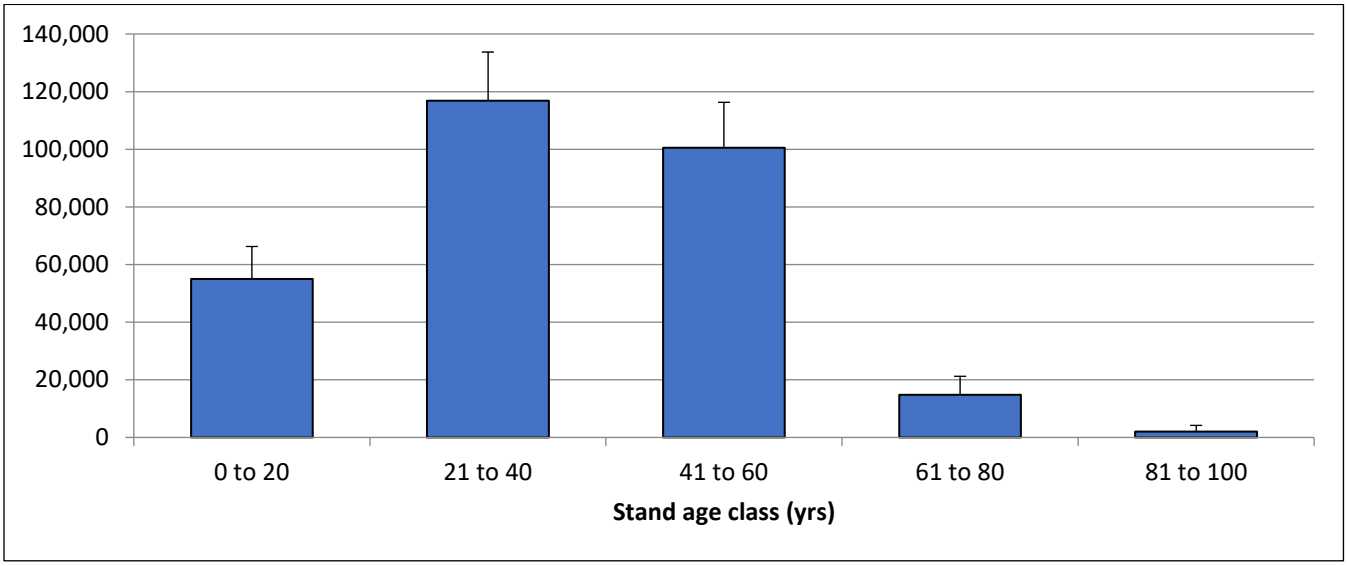


Figure 33.7. Jack pine age classes by volume in Wisconsin from the U.S. Forest Service's Forest Inventory and Analysis data (64).

Age-Class Distribution

There are both ecological and economic benefits to having a full range of age classes of a particular cover type across the landscape. Jack pine currently exhibits an unbalanced age class distribution with less acreage in the youngest and oldest age classes (64) (Figure 33.7). This reflects a decreased emphasis on reproducing jack pine in Wisconsin which is a concern for the future of the jack pine resource in Wisconsin. Moreover, the animal species associated with jack pine vary by stand age (107), and this age class imbalance is a problem for species

requiring young jack pine such as Kirtland's Warbler (see Endangered Threatened and Special Concern Species section).

3.1.3 Climate Change

Jack pine was ranked as moderately vulnerable to climate change in a recent vulnerability assessment (45). The report noted the species ability to compete on poor-quality sites, withstand disturbance, and persist with drought conditions. However, the species is at the southern extent of its range in Wisconsin, and it may be less able to persist and regenerate under substantial warming. USFS (45) hypothesizes that regeneration failure could occur more frequently in drought conditions, and pests and diseases could become more damaging.

Recommendations for Management

- Increase jack pine in the youngest age classes
- Use variety of techniques to naturally regenerate jack pine
- Provide openings, ideally focused on areas with better herbaceous plant diversity
- Limit conversion to other cover types in areas best suited for jack pine
- Create large block management areas of jack pine dominant forests, working to reduce fragmentation effects.
- Participate in rolling Barrens habitat projects, ideally at the landscape scale appropriate for the site. For example, in the Northwest Sands there would be a temporarily open core Barrens surrounded by 500-1000 acres of jack pine regeneration resulting in approximately 1000-2000 acres open at any given time where possible. However, this will be difficult in many areas, depending on ownership patterns.
- Plan rolling Barrens over the long term to create a landscape scale shifting mosaic.
- Modifications to timber management objectives and forest management guidelines (e.g., tree retention, biomass harvesting) may be appropriate to achieve site specific and landscape level objectives, such as Pine Barrens restoration.
- Consider landscape level management efforts that promote jack pine habitats, such as the Northwest Sands Habitat Corridor Plan (123), the Kirtland's Warbler Plan, and other related Conservation Opportunity Areas (COAs) as identified in the Wisconsin Wildlife Action Plan 2005 (118).

3.2 Site and Stand Considerations

3.2.1 Soils

Jack pine grows most commonly on level to gently rolling sand plains, usually of glacial outwash, fluvial, or lacustrine origin. These sandy soils are typically of the Spodosol or Entisol soil orders. Best growth occurs on well-drained loamy sands where the midsummer water table is within 4 to 6 feet of the soil surface. Jack pine will persist on very dry sandy or gravelly soils where other species can scarcely survive. It also grows on loamy soils, thin soils over bedrock, and peats.

Jack pine has been managed successfully on moist sands and peats, where seasonally-high water tables can provide suitable conditions for seed germination and seedling development.

Soil productivity considerations are important when managing the jack pine cover type for several reasons; jack pine commonly occurs on excessively drained/nutrient poor soils, rotations are relatively short, and whole-tree or biomass harvesting is common. These factors influence the availability of nutrients in the soil and thereby may alter the long-term stand productivity.

Wisconsin's Forestland Woody Biomass Guidelines (10) allow for biomass harvesting of jack pine on dry nutrient poor sandy soils as long as rotations are 40 years or longer. This exception for jack pine is based on the lower nutrient content of jack pine needles, twigs, and bark, as compared to other tree species. A Minnesota study found 765 lbs/acre calcium in above ground parts of aspen compared to only 181 lbs/acre calcium in jack pine (78). Based on nutrient budget calculations for these dry nutrient poor sandy soils, the soil nutrient pool is maintained with jack pine biomass harvests on rotations of 40 years or longer. Biomass rotations shorter than 40 years indicated depletion of the soil nutrient pool for certain nutrients, even in jack pine forests. Retention of fine woody material and rotation age determination are important considerations to maintain long-term site productivity in the jack pine cover type.

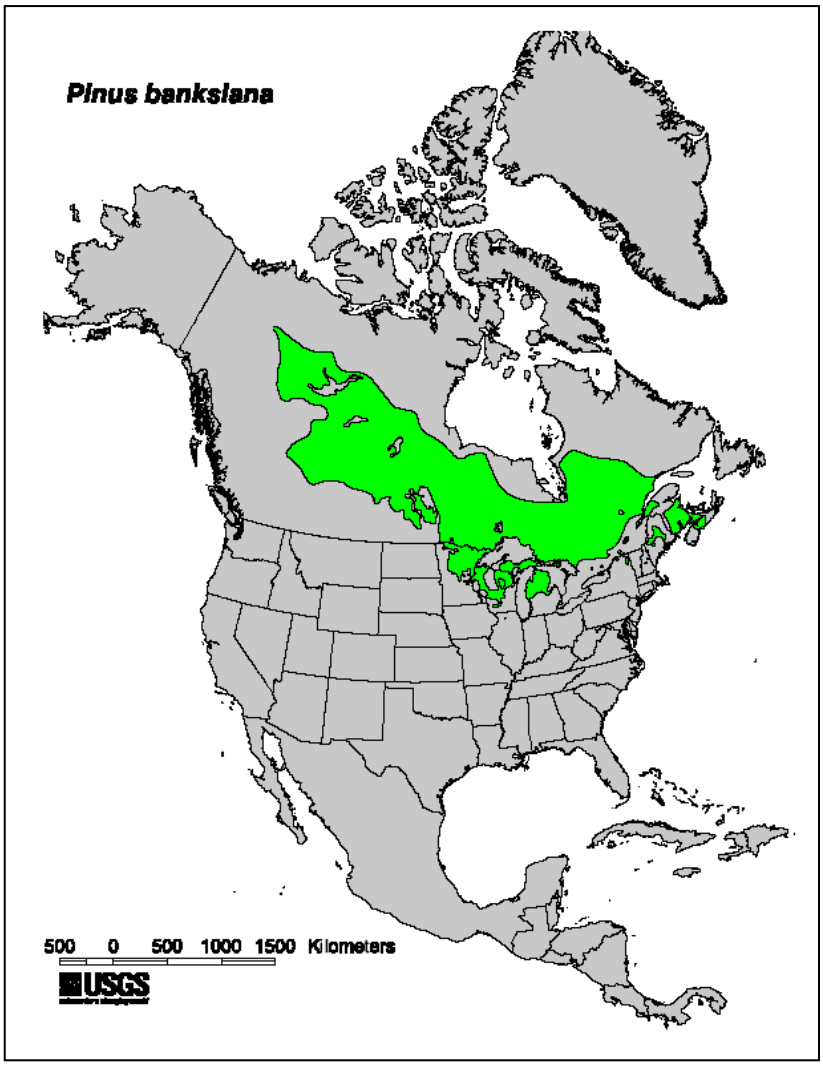


Figure 33.8. Native range of jack pine (57).

3.2.2 Site Quality

3.2.2.1 Range of Habitat Type

The range of jack pine is primarily located in Canada, extending from the Northwest Territories east to Nova Scotia, and then south into the New England and Great Lake states (Figure 33.8). At the northwest extremities of the range in Alberta, jack pine hybridizes with lodgepole pine (*Pinus contorta*) (93). In the United States, the largest acreages of jack pine are located on sandy soils in Minnesota, Wisconsin, and Michigan.

The jack pine cover type occupies approximately two percent (i.e. 307,500 acres) of the forestland acres in Wisconsin (64). Jack pine's statewide distribution is concentrated in the

Northwest Sands, Central Sand Plains, Northeast Sands, and Northern Highlands ecological landscapes (Figure 33.9). Approximately three-quarters of the jack pine volume is found on the sandy soils of northwest and central Wisconsin, with lesser amounts in the northeast, north-central and on other suitable habitats.

Jack pine is a pioneer tree species that historically regenerated almost exclusively after forest fires. Fire regimes of varying intensity and frequency resulted in pine-dominated ecosystems ranging from open Pine Barrens to very dense jack pine stands (83). Still today over three-quarters of all jack pine in Wisconsin is naturally occurring (i.e., not planted), a result of fire or scarification treatments and logging disturbance. However, with the advent of modern fire suppression practices, conditions for successful jack pine regeneration have been greatly diminished, resulting in a decline of the jack pine cover type. In the Northwest Sands, for example, the area of jack pine has decreased by 30% since pre-European settlement (83).

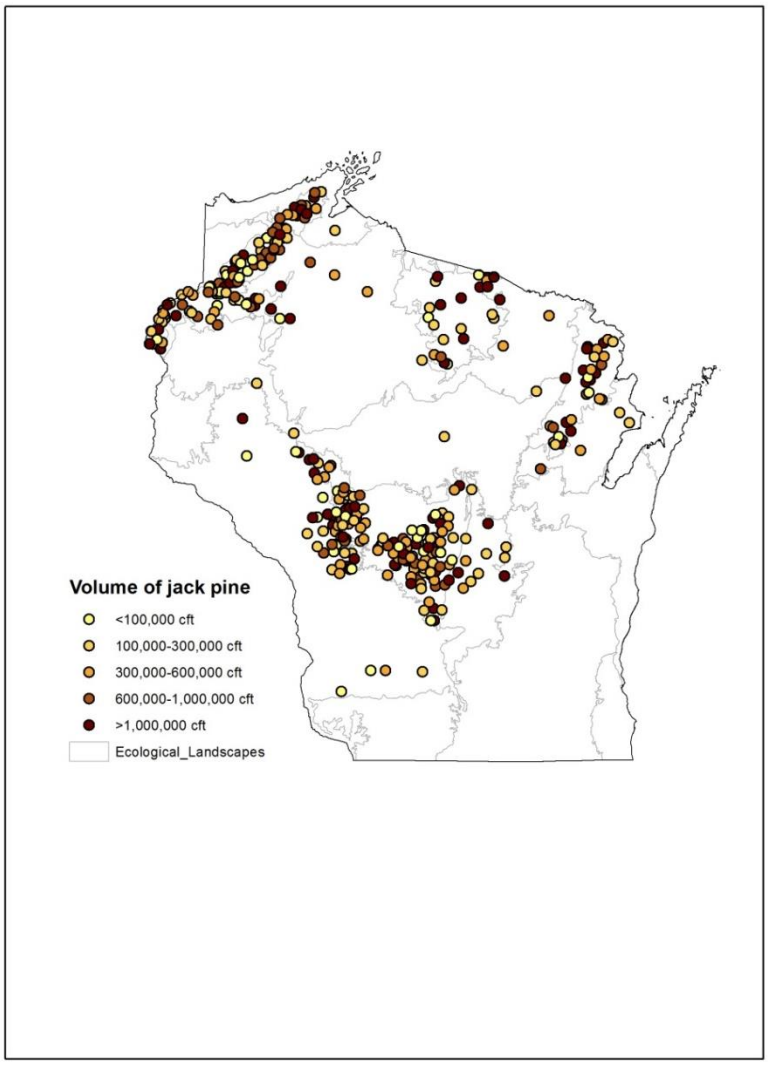


Figure 33.9. Volume of jack pine (cubic feet) by Ecological Landscape in Wisconsin from USDA FIA (64).

The volume of jack pine growing stock has been steadily decreasing in Wisconsin for poletimber and sawtimber (Figure 33.10). The ratio of removals to growth has more than doubled since 1983 and currently stands at 213% (64), meaning that harvesting removes twice as much volume as is being replaced by growth (Figure 33.11). The loss of jack pine acres and volume in Wisconsin is a result of high removals and high natural mortality (e.g., insects, disease, wind), coupled with poor regeneration and conversion to other species, such as red pine.

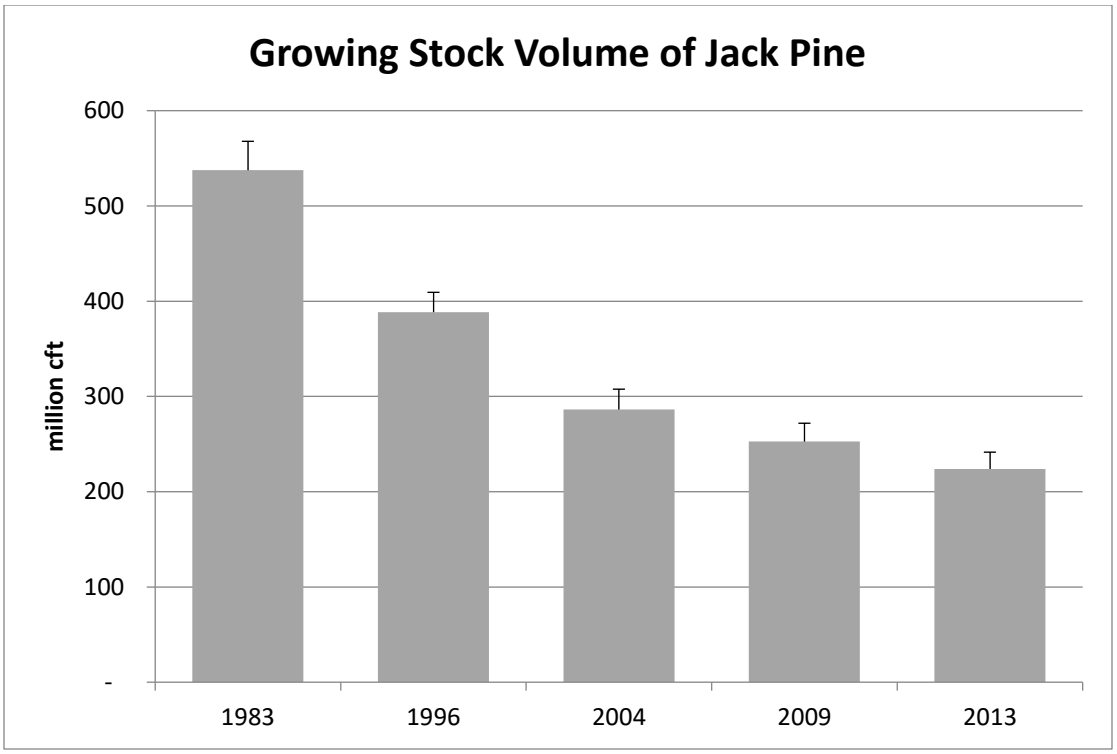


Figure 33.10. Growing stock volumes (million cubic feet) by inventory year from USDA FIA (64).

Northern Habitat Type Groups

Approximately 48% of the statewide jack pine volume occurs on northern habitat type groups, with most of that volume occurring on the northern very dry to dry (36%) and northern dry to dry mesic groups (7%). A small percentage occurs on the northern mesic to wet mesic group (4%), often associated with poorly drained sandy soils with ground water influences and low nutrients (Figure 33.12).

The northern very dry to dry habitat types are often associated with glacial outwash deposits of deep, excessively drained sands and include the driest and most nutrient poor ecosystems in northern Wisconsin. Jack pine is a common cover type on many of the habitat types in this group, but can also occur in mixed stands with pin, red, and bur oak, as well as with red and white pine. Jack pine and jack pine-oak mixtures are common on the PQE, PQG, PQGCe, PArV, PArV-U, PArVAo, and QAp habitat types (53). Jack pine ecosystems are dependent on fire or logging for regeneration and in the absence of these disturbances oak, white pine, and red maple become more abundant on this habitat type group.

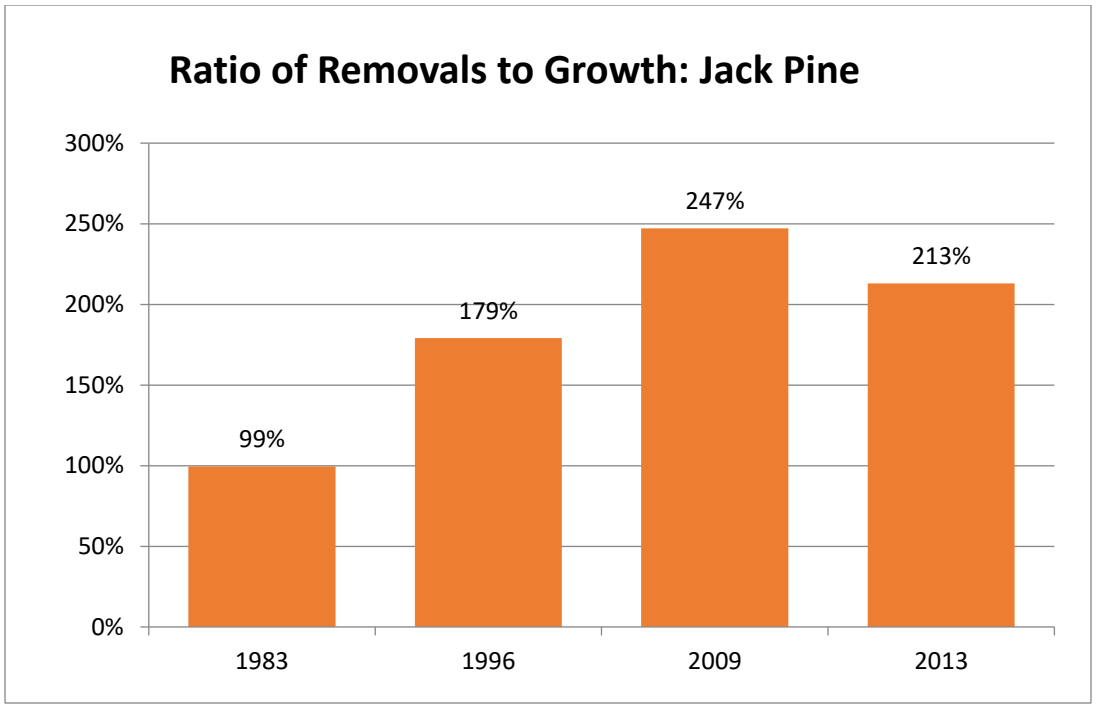


Figure 33.11. Ratio of volume harvested annually to net growth from USDA FIA (64).

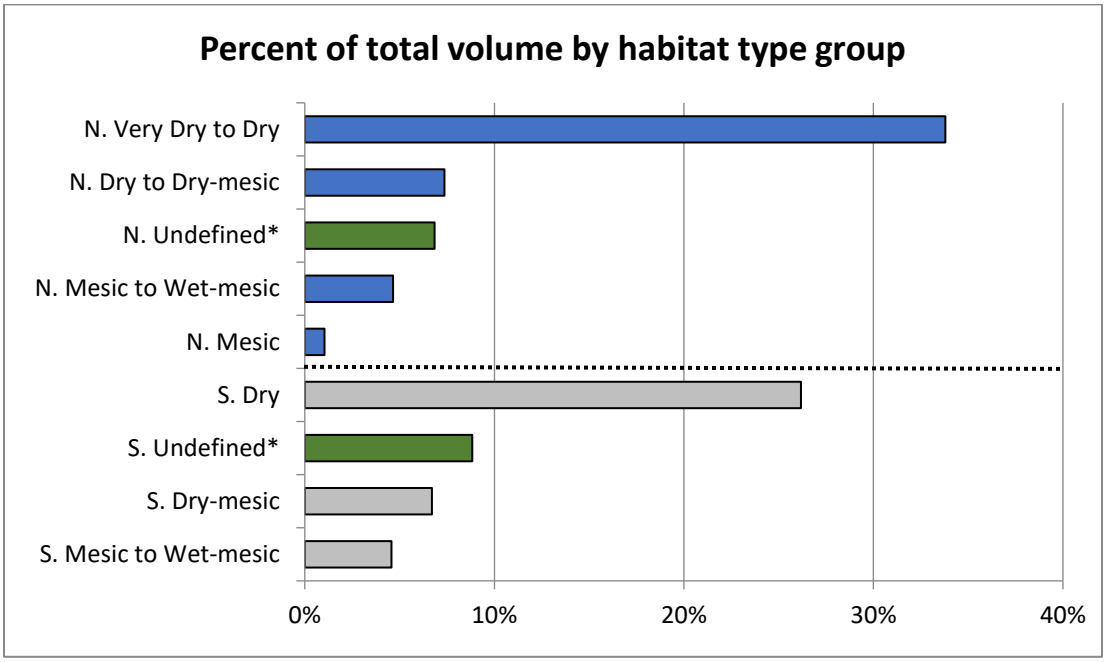


Figure 33.12. Percent jack pine volume by habitat type group from USDA FIA (64).

**Undefined groups contain FIA plots where no habitat type could be determined. Note: See Chapter 12 – Forest Habitat Type Classification System for information summarizing the system and the habitat type groups*.

The dry to dry-mesic habitat types have somewhat improved moisture and nutrient levels and therefore better growth potential for jack pine. This habitat type group includes glacial outwash sands, as well as moraines and lake plains with excessively to moderately well drained loamy sands and sands. Jack pine can be found on the PArVAm, PArVHa, PArVAa, PArVAa-Po, PArVAa-Vb, and PArVPo habitat types, but often in mixtures with competing associated species due to the improved growing conditions (53). All the habitat types in this group have the potential to grow large diameter, high quality jack pine. In the absence of disturbance, competition can be moderate to strong from red maple, white pine, and oak, contributing to continued losses in jack pine acreage due to natural conversion. In addition, jack pine stands are sometimes converted to red pine plantations due to its growth potential on these habitat types.

The northern mesic to wet-mesic habitat types where jack pine is found include poorly drained, sandy soils with high or perched water tables and poor nutrient regimes. Some habitat types in this group include ArVRp and PArVRh. Red maple and white pine usually develop in these stands in the absence of fire.

Southern Habitat Type Groups

Approximately 39% of the statewide jack pine volume occurs on southern habitat type groups, with most of that volume occurring on the southern dry (25%), southern mesic to wet-mesic (8%), and southern dry mesic groups (6%) (Figure 33.12).

The southern dry habitat types are located on nutrient poor sandy soils, often associated with glacial outwash deposits or residual material over sandstone. Topography is level to gently rolling, but these habitat types can also occur on steep slopes and narrow ridges. Jack pine in south-central Wisconsin exhibits less growth potential along the southern edge of its range, and is commonly associated with pin oak, white oak, black oak, aspen, red maple, red pine and white pine. Common habitat types in this group where jack pine are found include PVGy, PEu, PVCr, and PVG (52). In the absence of fire disturbance, white pine has become increasingly abundant on this habitat type group, especially in the central sands.

Jack pine occurs as an associate on the southern dry mesic habitat type, PVRh. This habitat type is similar to the dry types, except for ground water influences within 1-3 feet of the surface. White pine and red maple usually develop in these stands in the absence of fire.

Red Pine vs. Jack Pine Productivity

Red and jack pine grow on similar habitat types throughout the Lake States, including in mixed natural stands. However, forest managers have traditionally debated between either growing jack pine or red pine, typically favoring jack pine on the very dry sites and red pine on the somewhat more mesic sites. A Lake States study comparing volume productivity between red and jack pine plantations found that red pine mean annual increment averaged 29 cubic feet per acre greater than jack pine regardless of site index (1). These higher yields were primarily attributed to red pine’s ability to carry greater basal area per acre and to a lesser extent related to differences in site quality. This potential for increased yields has historically led to management decisions to convert natural jack pine stands to red pine plantations, especially on the dry to dry-mesic habitat types. However other studies have found that jack pine performance is generally greater in terms of average height growth and survival when compared to red pine, especially on dry outwash sands and when utilizing well-adapted or

improved seed sources (67, 93). Sustaining jack pine forests for economic (e.g., fiber supply) and ecological reasons (e.g., pine barrens, Kirtland's warbler), as well as recent forest health concerns with red pine plantations (e.g., annosum, pocket decline, climate adaptations), have led to renewed interest in jack pine reforestation. The decision to manage for jack pine, red pine, or mixed stands should be based on careful consideration of overall management objectives and site conditions.

3.2.5 Wildlife

Jack pine habitats in Wisconsin are concentrated into four main ecological landscapes; Northwest Sands, Central Sand Plains, Northeast Sands and Northern Highlands. Each of these landscapes supports a somewhat different suite of wildlife species. All of these landscapes were strongly influenced by fire disturbance, resulting in fire adapted vegetation and wildlife species that depend on frequent disturbance to provide suitable habitat. The Northwest Sands and Central Sand Plains contain the largest areas of jack pine forests, including many large blocks of public land which provide opportunities to manage for area-sensitive species, such as sharp-tailed grouse. The Northern Highlands contains a greater variety of landforms, soils, and forest types, and its abundant lakes, streams, and wetlands likely resulted in a somewhat less fire-prone landscape with less area of open conditions.

Jack pine stands provide an important habitat component for many wildlife species, depending on regeneration methods, stand development stage and stand size. Deer especially favor young stands of jack pine, or jack pine mixed with aspen and oak. A dense shrub layer in jack pine provides bedding and escape cover. As a browse, jack pine ranks as a secondary choice similar to white pine, less favored than hemlock or cedar, but preferred over red pine or balsam fir (29). Deer browse has still been a significant problem in some locations, especially on planted jack pine. A 2003 deer repellent trial on the Governor Knowles State Forest documented heavy browsing on jack pine seedlings, but application of deer repellents offered moderate protection (126). Research conducted at Sandhill Wildlife Area (Wood County) in oak/jack pine habitats found dewberry, blueberry, blackberry, and wintergreen were the most abundant perennial ground-layer plants that provided non-woody forage for deer in winter (54). The thermal protection provided by jack pine forests increases use by deer and other wildlife during the winter months.

Bear use all jack pine age classes for cover but prefer regenerating stands for summer and fall foraging areas, especially for berries. For many wildlife species, small openings within a regenerating stand are important for life history requirements including; nesting, foraging, mating, and rearing young. Ruffed grouse use middle-aged jack pine more commonly if mixed with a dense shrub understory and especially if associated with young or middle-aged aspen. Spruce Grouse use young to middle-age jack pine when associated with black spruce-tamarack bogs (3). Jack pine associated with conifer swamps are also preferred habitats for bobcat and fisher. Turkeys use mature jack pine as roost trees and forage in open stands of middle-age and mature jack pine. Small mammals, such as red squirrel, utilize the stored seed supply available from jack pine's serotinous cones.

Similar to game species, Species of Greatest Conservation Need (SGCN) use jack pine habitats according to the seral stages. Initially, if regenerating stands are open and large,

vesper sparrows and upland sandpipers use the new openings. Young dense stands with small openings are critical for Kirtland's warbler, as well as the more common brown thrasher and northern flicker. Limiting tall snags and perches may be a consideration in certain situations to reduce cow bird nest parasitism, such as within Kirtland's restoration areas. However, other wildlife species, such as black-backed and red-headed woodpeckers, will require snags. As jack pine stands mature and if a deciduous understory remains, Connecticut warblers find the habitat favorable. Mature stands will supply whip-poor-will habitat, especially near edges.

Thirty-one vertebrate SGCN were reported as being associated with Northern Dry Forest, a natural community type often dominated by jack pine (118). In addition, 33 SGCN were reported to be associated with the Pine Barrens community (118). Table 33.2 and Table 33.3 list the major jack pine-associated Species of Greatest Conservation Need. This list includes two WI Endangered species (Kirtland's warbler and slender glass lizard), and four WI Threatened species (spruce grouse, upland sandpiper, northern long-eared bat, and wood turtle). The Kirtland's warbler is also federally listed as endangered and the northern long-eared bat is federally listed as threatened. At least 21 invertebrate species designated as SGCN appear to use jack pine forests, including Pine Barrens (Table 33.3). The list includes one US Endangered species (Karner blue butterfly), three WI Endangered species (northern blue butterfly, phlox moth, and warpaint emerald dragonfly), and one WI Threatened species (frosted elfin).

Pine Barrens and Wildlife

Figure 33.13. A male sharp-tailed grouse displays among jack pine stumps and new growth. Photo by WDNR.

The Pine Barrens is a community characterized by variable densities of pine and oak, ranging from completely open areas to scattered trees to dense groves interspersed with openings. These communities are commonly associated with the dry nutrient poor sands and more fire prone landscapes, such as the Northwest Sands or Central Sand Plains, and support a unique mix of fire adapted flora. Wildlife species associated with the Pine Barrens range from the very common generalists (e.g., deer, snowshoe hare, turkey) to many rare and special concern species that are in decline due to loss of barrens habitat (see Landscape Considerations). Several species associated with the barrens are area-sensitive, meaning they require large, contiguous habitats to fulfill life history requirements. These large areas must

have a component of open habitat, at least temporarily, for many of the rarest barrens-dependent species. In the Northwest Sands, sharp-tailed grouse are considered an indicator species for quality barrens communities. Sharp-tailed grouse make use of jack pine stands mainly in early regeneration stages, especially in areas of large block management and rolling barrens (see Landscape Considerations). Landscape level planning and implementing large scale cooperative projects is critical to restoring landscape function in the barrens community. Forest management and working forests, particularly jack pine harvesting and regeneration, play a key part in successful barrens management.

Wildlife Recommendations

- Consider regenerating jack pine stands in order to offset declines in this forest cover type.
- Consider landscape context; adjust stand size and placement where appropriate in order to achieve large blocks of jack pine habitat, including blocks of various age classes. The age class blocks can be rotated over time, as in rolling barrens management (Figure 33.5).
- Allow for variable densities during the regeneration stage, creating dense patches and small openings (i.e., generally less than ½ acre in size).
- Consult with local biologists to determine where tree retention is appropriate to meet stand-level and landscape-level objectives.
- Use the least intensive site preparation methods possible to maintain ground flora, while achieving regeneration objectives. Consider not treating small areas where rare species occur (i.e., refugia).

3.2.6 Endangered, Threatened and Special Concern (ETS) Species

Jack pine can be the dominant species in two major natural community types: Northern Dry Forests and Pine Barrens. These closely related, disturbance-dependent community types support a number of rare species and often form a continuum from very open to more closed-canopy forest. Maintaining both of these communities on the landscape is important for conserving rare species, and there can be ecological benefits to managing them together, even within the context of timber production.

Pine Barrens are not just recently logged or otherwise treeless areas, and they can vary greatly in structure and species composition. These areas can contain a unique flora, including species associated with dry prairie habitats. The Pine Barrens community found in Wisconsin is considered globally imperiled because there are so few high-quality examples remaining (128). Wisconsin's barrens are different from the "barrens" of the eastern U.S. which lack much of the floristic diversity present in this type in the Lake States (127). The structure of the barrens can range from almost completely open to partially open with patches of larger trees.

Some of Wisconsin's rarest plants and animals are associated with Pine Barrens communities. These include numerous WI Threatened species, as well as WI Endangered species such as slender glass lizard (*Ophisaurus attenuatus*), phox moth (*Schinia indiana*), and dwarf huckleberry (*Vaccinium cespitosum*), the only known host plant for the northern blue butterfly (*Lycaeides idas*) which is also WI Endangered. The US Endangered Karner blue butterfly

(*Lycaeides melissa samuelis*) uses Pine Barrens, as well as other open to semi-open habitats in sandy ecological landscapes if they contain its host plant, lupine (*Lupinus perennis*). Frosted elfin (*Callophrys irus*), a much rarer butterfly in Wisconsin that is found only in the Central Sand Plains ecological landscape, also relies on lupine as its host plant.

Some barrens species are area-sensitive including Sharp-tailed Grouse (*Tympanuchus phasianellus*), a WI Special Concern species that requires very large, contiguous habitats to support viable populations. Its best Wisconsin populations are located in large managed areas in the Northwest Sands. Connecting scattered openings and pockets into larger blocks could benefit a number of species, and these open areas could be managed in conjunction with the surrounding forests (see Landscape Considerations).

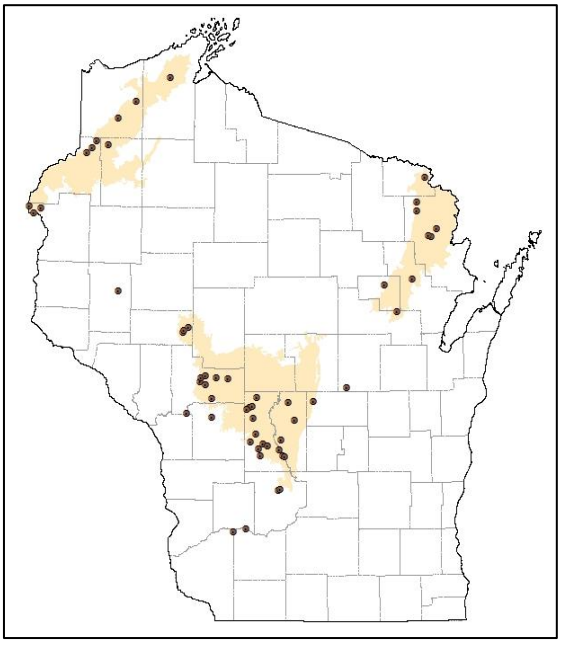


Figure 33.14. Location of Pine Barrens remnants documented in the NHI database (dots) in the Northwest Sands, Northeast Sands, and Central Sand Plains ecological landscapes. Many of the species described in this section are found in these landscapes.

Most of the rare plants associated with the more closed-canopy jack pine forests (Northern Dry Forest community) are barrens associates that have survived where light and other conditions have remained favorable. Sometimes these species can be present in the seed bank and return following logging, burning, or a combination of the two. Whether a stand can support some of the flora associated with barrens will depend on the stand's location, its disturbance history, and the amount of light reaching the understory.

Maintaining pockets of open barrens within jack pine plantations can be important for increasing species diversity since a normal timber rotation may be too long to support some of the light-demanding plants associated with barrens communities. Providing openings in jack pine plantations has been described as vital for the maintenance of barrens species (44). Ideally, planted sites would include permanent or semi-permanent open areas, where feasible, and these would be located where high-quality barrens remnants exist. Sometimes these pockets can support additional animal species such as certain butterflies and moths which usually rely on specific plant species to complete their life cycle.

More closed-canopy forests dominated by jack pine can support several animal species such as Connecticut warbler (*Oporornis agilis*) and spruce grouse (*Falcipennis canadensis*). The jack pine forests of northwest Wisconsin are an important stronghold for Connecticut warbler where it uses dense stands of older jack pine (131). Spruce grouse has been found in jack pine forests near lowland conifer swamps, especially in winter (4, 124), and these lowland areas provide critical nesting habitat. Table 33.2 lists additional rare vertebrate species associated with jack pine communities.

Kirtland's Warbler

Kirtland's warbler (*Setophaga kirtlandii*), a US Endangered species since 1967, is probably the most well-known animal species associated with jack pine. In its core breeding range in the northern part of Lower Michigan, there is evidence that populations were at their highest in recorded history at the same time jack pine habitat was most abundant during the 1880s and 1890s . It has been the focus of major recovery efforts, formerly mostly in Michigan, for several decades (75).

Figure 33.15. Planting pattern in a Kirtland's Warbler management area, Huron-Manistee National Forest, Michigan. Photo by Linda Haugen, USDA Forest Service Bugwood.org.

In Wisconsin, Kirtland's warbler has been documented in several ecological landscapes but is known to breed in just two locations, as of this writing. Its habitats are highly specialized; it generally breeds in jack pine stands from 6-23 years old, with tree heights ranging from 5.5 to 16.5 feet tall, and in stands of 75 to 100 acres or larger (82).

In Lower Michigan, intensive management techniques conducted through state and federal agencies have proven highly successful for increasing numbers of Kirtland's warbler. Populations increased from about 400 individuals in 1971 to 3600 by 2012 (48). Approximately 2,000-2,500 acres of jack pine are established annually using a wave planting pattern in order to create small openings (75), and it also provides habitat for a number of other wildlife species (24). The trapping of cowbirds, a parasitic songbird that often prevents successful nesting by Kirtland's warbler, has been critical to the success of these efforts in recent years (75). However, this approach differs greatly from natural disturbance (27, 24) and does not provide the level of diversity that would be found in most barrens. The impacts of this approach on plant and animal diversity have become important research questions (25, 66, 101) and the focus of recent efforts in the Upper Great Lakes. One concern is that this intensive approach leads to a homogenous landscape if applied over very large scales. Recent efforts in Michigan have focused on examining similarities and differences between this type of management and natural fire disturbance, as well as ways to incorporate burning, patch retention, and other barrens management into the management for Kirtland's warbler (25). Wisconsin, being recently colonized by Kirtland's warbler, may have the opportunity to incorporate a broad range of considerations into management for this species.

The first documented breeding location for Kirtland's warbler in Wisconsin was dominated by red pine, but most red pine plantations would not be able to support this species. A high degree of red pine mortality combined with abundant natural jack pine recruitment created the conditions that allowed Kirtland's warbler to utilize this central Wisconsin site (3). There may be opportunities to grow red pine in coordination with jack pine in an attempt to mimic the

conditions of this site while making it more economically attractive to manage for jack pine in certain areas (3). See the USFWS Kirtland's warbler website (105) for more information.

Other considerations for jack pine communities include the impact of chemical and mechanical site preparation techniques on the flora and fauna of the barrens and dry forests. These communities clearly require disturbance to persist, and there are several aggressive invasives that need control. Moreover, some rare plants have been shown to respond favorably to disturbances such as scarification. However, the impacts of some techniques on many rare species are not completely clear at this time. A careful approach is warranted where rare species occur, including consideration for not treating certain areas or limiting certain areas to spot-treatments when using herbicides. A biologist can help with planning these decisions.

Table 33.2, Table 33.3 and

Table 33.4 list many of the species known to use habitats dominated by jack pine. For more information and guidance on these and other rare species, as well as information on natural communities, and ecological landscapes, see the following resources:

- Wisconsin DNR's rare plant, animal, and natural community web pages: *dnr.wi.gov* keyword "biodiversity"
- Ecological Landscapes of Wisconsin: dnr.wi.gov keyword "landscapes"
- Wisconsin DNR's Natural Heritage Working List: dnr.wi.gov keyword "nhi"

Figure 33.16. Photos: (Left) Karner Blue habitat. Pine Barrens in Adams County, Photo by WDNR. (Right) Pine Barrens understory with wild lupine, cylindrical blazing-star, lance-leaved loosestrife, prairie grasses, Eau Claire County. Photo by Eric Epstein.

Table 33.2. Wisconsin Vertebrate Species of Greatest Conservation Need (SGCN, 2005) that use jack pine forests. See also dnr.wi.gov keyword "biodiversity."

Common Name	Scientific Name	State Status[1]	Federal Status[2]	Forest Stage [3]				Season [4]			Locations[5]	Comments
				R	Y	M	O	YR	W	S		
Birds												
American Woodcock	*Scolopax minor*	SC		xx	xx	xx				xx	Nearly statewide	Not primarily associated with jack pine but may use it.
Black-backed Woodpecker	*Picoides arcticus*	SC				xx	xx	xx			Northernmost ecological landscapes	Retain cavities and dead trees for nesting. Often nests where tree density is higher.
Black-billed Cuckoo	*Coccyzus erythropthalmus*	SC			xx	x				xx	Nearly statewide	Found most in extensive tracts of forest. Uses several forest types.
Boreal Chickadee	*Poecile hudsonicus*	SC				xx		xx			Northernmost ecological landscapes	Not primarily associated with jack pine. Uses lowland conifers in WI.
Brown Thrasher	*Toxostoma rufum*	SC			xx	xx				xx	Nearly statewide	Brushy habitats; edge species. More associated with barrens / prairies.
Connecticut Warbler	*Oporornis agilis*	SC				xx	xx			xx	Northernmost ecological landscapes and CSP	Prefers mature, multi-layered stands.
Field Sparrow	*Spizella forsteri*	SC		xx						xx	Nearly statewide except the most forested northern landscapes.	Early successional species that could be in barrens or very young forest following disturbance.
Grasshopper Sparrow	*Ammodramus savannarum*	SC		x						x	Nearly statewide except the most forested northern landscapes but mostly found in the south.	Grassland / barrens species that avoids tall, dense vegetation.
Kirtland's Warbler	*Setophaga kirtlandii*	END	LE	xx	xx					xx	NWS, NH, NES, CSP	Requires jack pine of a certain size class and in larger blocks; see text.
Lark Sparrow	*Chondestes grammacus*	SC		xx	x					xx	Southern and western ecological landscapes	Early successional species that could be in barrens or very young forest following disturbance.
Least Flycatcher	*Empidonax minimus*	SC				x	x			xx	Nearly statewide	Can be found in a variety of forested habitats.
Northern Harrier	*Circus cyaneus*	SC		xx						xx	Nearly statewide	Species of very open habitats that nests on the ground. Does not use forests.

Common Name	Scientific Name	State Status[1]	Federal Status[2]	Forest Stage [3]				Season [4]			Locations[5]	Comments
				R	Y	M	O	YR	W	S		
Red Crossbill	*Loxia curvirostra*	SC					xx		xx	x	Mostly northernmost ecological landscapes but could be found in almost any EL.	Mature coniferous forests and relies on seed cones. Breeding locations change based on locations of good seed crops.
Red-headed Woodpecker	*Melanderpes erythrocephalus*	SC					xx		x	xx	Nearly statewide except the most forested northern landscapes.	Savanna / barrens species that uses various species of oaks. Not directly tied to jack pine.
Sharp-tailed Grouse	*Tympanuchus phasianellus*	SC		xx				xx			Northern WI and CSP Best habitats are in the NWS	Uses large areas with dense. herbaceous cover and shrubs.
Spruce Grouse	*Falcipennis canadensis*	THR				xx	xx		xx	x	Northernmost ecological landscapes	Prefers dense stands. Jack pine stands adjacent to lowland conifers appear to be important in WI. Seems to avoid stands with high component of deciduous trees.
Upland Sandpiper	*Bartramia longicauda*	THR		xx	xx					xx	Nearly statewide except the most forested northern landscapes.	Grassland / barrens species that avoids tall, dense vegetation.
Vesper Sparrow	*Pooecetes gramineus*	SC		xx	xx					xx	Nearly statewide except the most forested northern landscapes.	Grassland / barrens species that avoids tall, dense vegetation.
Whip-poor-will	*Caprimulgus vocifeus*	SC				xx				xx	Nearly statewide	Prefers forest with little underbrush that is close to foraging areas (open areas).
Mammals												
Gray Wolf	*Canis lupus*	SC		x	x	x	x	xx			Northern and central WI	Not primarily associated with jack pine but may use it along with many other forest types.
Hoary Bat	*Lasiurus cinereus*	SC				x	xx			xx	Statewide	Roost in large, mature trees.
Moose	*Alces alces*	--		x	xx				xx		Rarely move into WI from MI - usually only the northernmost counties	Can be found in a variety of forests and wetlands.
Northern Flying Squirrel	*Glaucomys sabrinus*	SC				x	xx	xx		xx	Northernmost ecological landscapes	Conifer or mixed forests with standing dead trees, coarse

Common Name	Scientific Name	State Status[1]	Federal Status[2]	Forest Stage [3]				Season [4]			Locations[5]	Comments
				R	Y	M	O	YR	W	S		
												woody debris and diverse understory.
Northern Long-Eared Bat	*Myotis septentrionalis*	THR				xx	xx			xx	Statewide	Roosts in a wide variety of tree species in intact forests.
Herptiles												
Blanding's Turtle	*Emydoidea blandingii*	SC		xx	x	x				xx	Nearly statewide, except far north-central counties	Species is primarily aquatic but will traverse a variety of terrestrial habitats in the active season. Nests in open sandy areas within 900 ft. of a wetland or waterbody. This is a consideration for siting landings or roads.
Gophersnake	*Pituophis catenatus*	SC		xx						xx	Western and southwestern 1/3 of the state	Prairie/savanna/barrens species. Needs open habitat.
Prairie skink	*Plestiodon septentrionalis*	SC		xx						xx	Northwestern WI	Sandy barrens, savannas, prairies, and dry forests. Active from May – September.
Slender Glass Lizard	*Ophisaurus attenuatus*	END		xx						xx	CSH, CSP, and WCR ecological landscapes	Barrens, prairies, and savannas. Needs sandy soils but will use forest edges.
Wood Turtle	*Glyptemys insculpta*	THR		x	x	x	x			xx	Northern 2/3 of the state	Species is very terrestrial during the active season and utilizes a mosaic of forest and open habitats. Nests in open sandy areas, often within 200 ft. of a wetland or waterbody, but individuals can be found much farther from their overwintering streams. This is a consideration for timber harvests, as well as siting of landings or roads.

1. END = Endangered, SC = Special Concern, THR = Threatened. Note some SC species are protected by other laws; see WDNR 2014b for more information.
2. LE = Listed Endangered by the US Fish and Wildlife Service
3. Forest Stage: R=regenerating, Y=young forest, M=Mid-age forest, O=older forest; xx= major use; x= minor use
4. Season: YR=year-round, W=Winter, S=Summer season; xx= major use; x= minor use
5. Ecological Landscape abbreviations: CSP = Central Sand Plains, NH = Northern Highlands, NES = Northeast Sands, NWS = Northwest Sands (see *dnr.wi.gov* keyword "landscapes" for more information).

Table 33.3. Select Wisconsin invertebrate SGCN that use jack pine forests. See also dnr.wi.gov keyword "biodiversity." For grasshopper guidance, see Kirk and Bomar (48), the source of some of this information.

Species	Scientific Name	State[1] Status	Federal Status[2]	Ecological Landscape(s)[3]
Speckled Rangeland Grasshopper	*Arphia conspersa*	SC		Sandy gravel soils in dry prairie settings such as open sand in Pine Barrens and Lake Superior sand spits.
Frosted Elfin	*Callophrys irus*	THR		Pine barrens, oak savanna, and edges of sandy oak/pine forest.. Needs lupine (*Lupinus perennis*), its larval host plant. (CSP only).
Rocky Mountain Sprinkled Locust	*Chloealtis abdominalis*	SC		Jack pine barrens, pine forest openings.
Tiger Beetle	*Cicindela longilabris*	SC		Sandy areas in coniferous forest with jack pine, blueberries, reindeer moss. Sandy roads, gaps in northern forest.
Tiger Beetle	*Cicindela patruela huberi*	SC		Dry, sandy soils within mixed jack pine-oak forest and pine barrens, usually along forest roads and sand quarries.
Tiger Beetle	*Cicindela patruela patruela*	SC		Dry, sandy soils within mixed jack pine-oak forest and pine barrens, usually along forest roads and sand quarries.
Wild Indigo Dusty Wing	*Erynnis baptisiae*	SC		Dry open woods, prairie including wet prairie, pine/oak barrens, and along highways and railroad right-of-ways.
Mottled Dusty Wing	*Erynnis martialis*	SC		Scrub forest, pine/oak barrens and oak savanna.
Persius Dusky Wing	*Erynnis persius*	SC		Pine/oak barrens, sand barrens. Microhabitat includes open sandy ground and small scrub oaks may be required components of the habitat.
Slender Clearwing	*Hemaris gracilis*	SC		Jack pine/oak barrens and open trails through northern dry forests (NWS only).
Cobweb Skipper	*Hesperia metea*	SC		Pine barrens and oak savanna.
Northern Blue Butterfly	*Lycaeides idas*	END		Only found in association with the larval host plant, dwarf bilberry (*Vaccinium caespitosum*), which is also State endangered. (NES only).
Karner Blue Butterfly	*Lycaeides melissa samuelis*	SC	LE	Found in pine barrens and oak savanna, as well as a number of other open or partially-open sandy habitats with its larval host plant lupine (*Lupinus perennis*).
Huckleberry Spur-throat Grasshopper	*Melanoplus fasciatus*	SC		Sandy woods and pine/oak barrens with jack pine, blueberry, sweet fern, and lupine.

Species	Scientific Name	State[1] Status	Federal Status[2]	Ecological Landscape(s)[3]
Stone's Locust	*Melanoplus stonei*	SC		Pine/oak barrens and northern dry-mesic forest (in CSP), high quality sand dunes on Lk. Michigan shore.
Chryxus Arctic	*Oeneis chryxus*	SC		Dry grass habitats, cutovers, jack pine barrens, rocky and grassy openings in forest especially along ridges.
Pink Sallow Moth	*Psectraglaea carnosa*	SC		Usually in unburned sandy pine or oak barrens. Apparently absent from many barrens less than 2000 acres.
Sprague Pygarctica Moth	*Pygarctia spraguei*	SC		Pine barrens and oak savanna in Wisconsin.
Bina Flower Moth	*Schinia bina*	SC		Pine barrens supporting native hawkweeds.
Phlox Moth	*Schinia indiana*	END		Sandy dry to dry-mesic savannas (black/Hill's oak or jack pine barrens) and small dry-mesic prairie openings with an abundance of downy phlox (*Phlox pilosa*), its host plant.
Warpaint Emerald Dragonfly	*Somatochlora incurvata*	END		Large wetlands often adjacent to sandy uplands (old beach ridges) consisting of jack pine, red pine, and northern pin oak.

1. END = Endangered, SC = Special Concern, THR = Threatened. Note some SC species are protected by other laws; see WDNR 2014b for more information.
2. LE = Listed Endangered by the US Fish and Wildlife Service
3. CSP = Central Sand Plains, NES = Northeast Sands, NWS = Northwest Sands (see *dnr.wi.gov* keyword "landscapes" for more information).

Table 33.4. Select Wisconsin rare plants known from Northern Dry Forest and Pine Barrens. See also *dnr.wi.gov* keyword "biodiversity."

Common Name	Scientific Name	Community Type [1]	State Status [2]	Documented Habitat
Prairie Sagebrush	*Artemisia frigida*	PB	SC	Very dry dolomite bluff prairies and sand terraces along the upper Mississippi River; adventive elsewhere.
Wooly Milkweed	*Asclepias lanuginosa*	PB	THR	Dry, sandy or gravelly hillside prairies.
Dwarf Milkweed	*Asclepias ovalifolia*	PB	THR	Oak barrens, open pockets within pine barrens, periodically brushed areas, and rights-of-way.
Fernald's Sedge	*Carex merritt-fernaldii*	PB, NDF	SC	Dry sandy soils and rocky outcrops in central, north-central, and northeastern Wisconsin. It is usually found in recently burned barrens, and occasionally in low, moist sandy areas along lake margins or roadsides.
Grassleaf Rush	*Juncus marginatus*	PB	SC	Acidic, peaty ditches and depressions in pine and oak barrens.
Large-Flowered Ground-Cherry	*Leucophysalis grandiflora*	PB, NDF	SC	Mostly in recently burned or disturbed moist to dry forests, as well as on gravel bars of large rivers.
Brittle Prickly-Pear	*Opuntia fragilis*	PB	THR	Thin, dry soil over rock, as well as sand prairies.
Hairy Beardtongue	*Penstemon hirsutus*	PB	SC	Dry gravelly and sandy prairies, or in hillside oak woodlands. It is also naturalized on roadsides.
Pale Beardtongue	*Penstemon pallidus*	PB	SC	Dry, often calcareous prairies, as well as hillside oak or jack pine woodlands. It is naturalized on roadsides and in pine plantations.
Hooker's Orchis	*Platanthera hookeri*	NDF	SC	Variety of dry to moist, mostly mixed coniferous-hardwood forests.
Catfoot	*Pseudognaphalium micradenium*	PB, NDF	SC	Dry, commonly sandy soil, often in open oak and pine woods and barrens.
Prairie Fame-Flower	*Phemeranthus rugospermus*	PB	SC	Open, sandy prairies, barrens and in moss on exposed bedrock outcrops, often where there is little competition from other forbs.
Dwarf Huckleberry	*Vaccinium cespitosum*	PB, NDF	END	Pine barren openings and can often be located by searching for the WI Endangered northern blue butterfly whose larvae feed exclusively on this shrub.
Blue Ridge Blueberry	*Vaccinium pallidum*	PB	SC	Dry, upland woods and old fields. Known only from northeastern counties in WI.
Sand Violet	*Viola sagittata var. ovata*	PB	END	Dry, sandstone road cuts or trailside with little competition other than jack pine.

1. PB = Pine Barrens, NDF = Northern Dry Forest
2. None of these species were federally-listed at the time of this writing.

3.2.7 Economic Issues

Primary Wood Using Industries

Jack pine is utilized by primary wood using industries as pulpwood, biomass, posts, and sawlogs. In 2009, jack pine accounted for 13 million cubic feet or 3.6% of Wisconsin's total

roundwood production, with approximately 56% used for pulpwood and 33% for sawlogs (125). Jack pine is a desirable pulpwood species because of its long fiber length, making it ideal for producing strong paper. Wisconsin paper mills generally lump jack pine with other conifer species and process softwood and hardwood pulpwood separately. Jack pine lumber is generally knottier than other hard pine species, such as red pine, and is often grouped with other softwoods like spruce, pine, and fir and stamped with the abbreviation “SPF” (132). A few Wisconsin sawmills have developed good markets for jack pine dimensional lumber (e.g., SPF lumber, pallet stock, fence pickets), specifically targeting 8’to 12’ sawlog lengths.

Current Statewide Inventories

The statewide growing stock volume of jack pine in 2013 was approximately 224 million cubic feet. This represents a decrease of 57% since 1983 (Figure 33.10). Jack pine growing stock volume has been decreasing steadily due to high removals and natural mortality, coupled with poor regeneration and conversion to other species. The ratio of removals to growth has more than doubled since 1983 and currently stands at 213% (Figure 33.11). The number and volume of pole and sawtimber trees has decreased significantly since 1996, but the number of saplings has increased by about 10%, suggesting some level of successful regeneration for this forest type (125).

Wisconsin paper mills report concern for limited supplies of jack pine, as well as other softwood species. Jack pine has become a smaller portion of their softwood volumes, due to the decreasing supply and diversion of larger trees to sawtimber markets. Wisconsin mills that utilize jack pine also indicate they would purchase more volume if it was available, but even at small volumes jack pine is still an important component of their overall product mix (Joseph Kies, personal communication).

General Product Specifications:

Pulpwood

- Length – 100”
- Minimum Diameter (small end) – 3” or 4”
- All softwoods scaled by weight
- No charred wood

Sawtimber

- Length – 8’, 10’, or 12’ sawlogs (plus 6” trim)
- Minimum Diameter (small end) – 8”

3.2.8 Wildfire Protection

Fuel Management for Reducing Wildfire Hazards

Fuel management considerations should be made in jack pine communities, prioritizing areas adjacent to developed residential areas. There are two main types of fuel management options to consider: fuelbreaks and firebreaks.

Fuelbreaks: A fuelbreak is a natural or man-made change in fuel characteristics which affects fire behavior so that fires burning into them can be more readily controlled (73). Strategically

locating fuelbreaks near developments and within larger blocks of pine will reduce the risk of crown fire and create tactical opportunities for fire suppression personnel and equipment if a forest fire should occur. A fuelbreak will lower the fuel volume and reduce fire intensity by using techniques such as thinnings, harvest and species conversion. A fuelbreak does not stop a wildland fire; rather the focus is on interrupting the contiguous fuel arrangement so that the canopies will not sustain fire.

Jack pine thinnings and harvest will reduce the amount of fuel that sustains crown fire, causing a fire to drop to or remain on the forest floor where suppression crews are better able to control or narrow the fire. Post-harvest slash near houses should be mitigated. Mechanically treating fuels (e.g., roller chopping) to create a fuelbreak can also serve as a wildlife opening.

During species conversion, less hazardous associated species are favored as determined by location and habitat type. Scrub oak, aspen and white birch are common associates that should be considered for conversion as well as opportunities for oak savanna or Pine Barrens. Aspen can actually slow a fire once they have greened-up. Widths can be delineated by features in the area (e.g., from road to road or lake to lake).

Another consideration is floating fuelbreaks. Use progressive clearcut methods by maintaining separate harvest areas in strips, so there is always one strip of low vegetation that can be considered a fuelbreak and access point for fire suppression equipment.

Firebreaks: A firebreak is a natural or constructed barrier used to stop or check fires that may occur, or to provide a control line from which to work (73). The objective of a firebreak is to remove all burnable material from an area. Two considerations are the placement of roadside mineral soil firebreaks and logging or access roads. Mineral soil firebreaks on the sides of plantations next to roads can provide suppression opportunity. They can also prevent a roadside surface fire from burning into the plantation.

Logging road locations should be designed to maximize their value as firebreaks. Include 20-foot wide fire breaks/access roads within larger plantations for suppression opportunity.

4 STAND MANAGEMENT DECISION SUPPORT

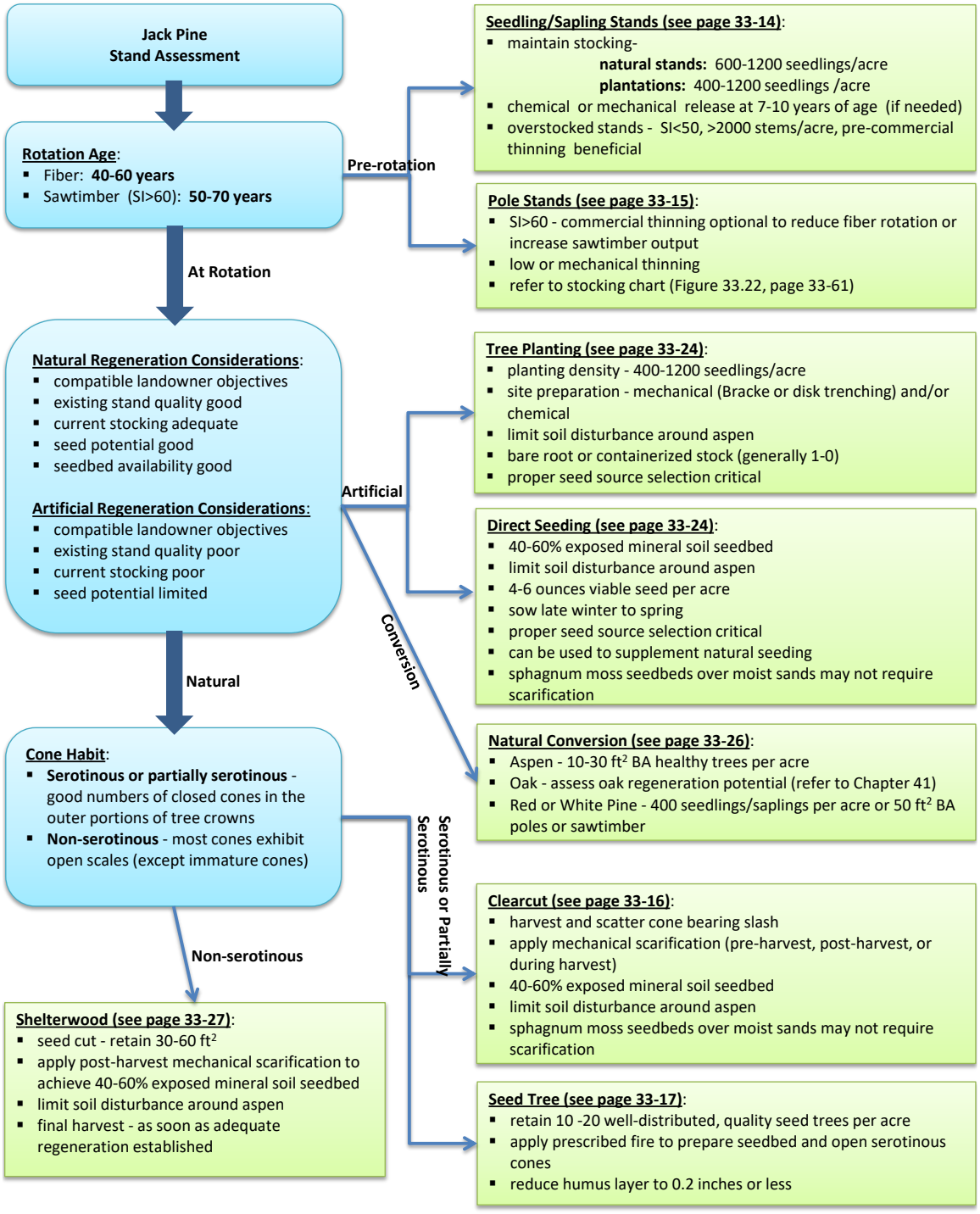
4.1 Stand Inventory

Prior to development and implementation of silvicultural prescriptions, landowner property management goals need to be clearly defined and articulated, management units (stands) must be accurately assessed, and stand management objectives should be detailed. In-depth and accurate stand assessment will facilitate discussion of stand management options and objectives in relation to realistic and sustainable management goals. Jack pine stand assessment may include quantifying variables such as those described in the following table.

Table 33.5. Jack pine stand inventory considerations.

Species Composition	• Canopy, shrub, and ground layers • Potential growth and competition • Sources of regeneration, especially non-target species that may interfere with jack pine regeneration (e.g., aspen coppice)
Stand Structure	• Size class distribution and density • Age class distribution
Stand and Tree Quality	• Overall stand health and vigor • Crown form and vigor • Stem form and quality • Potential products (fiber vs. bolt wood) • Genetic potential of current stand (Note – past improper seed source selection may have resulted in poorly adapted planting stock)
Regeneration Potential	• Cone production • Serotinous vs. non-serotinous • Seedbed condition – scarification needs • Depth to water table – available moisture • Competing vegetation (e.g., hazel, sedge)
Site Quality	• Habitat type • Site index • Soil characteristics
Damaging Agents	• Gall rust • Jack pine budworm damage • Browse
Special Considerations	• Stand history • Wildlife objectives • Rare species presence or potential habitat • Landscape context • Rare or declining natural communities (e.g., Barrens)

4.3 Cover Type Decision Model



5 SILVICULTURAL SYSTEMS

A silvicultural system is a planned program of vegetation treatment during the entire life of a stand. Silvicultural systems typically include three basic components: intermediate treatments (tending), harvesting, and regeneration.

5.1 Seedling / Sapling Stands

Jack pine germination and early seedling establishment is usually best on sites where there is some shade cast by slash and snags to reduce surface temperatures and drying. Subsequent early growth however is best in full sunlight with limited competition from shrubs and herbaceous vegetation (94).

Under forest conditions, seedling growth is generally slow in the first 3 years but increases rapidly beginning in the fourth and fifth years (94). Once established, seedlings and saplings exhibit optimal vigor (growth and health) when exposed to full sunlight. Delayed germination following disturbance combined with slow initial seedling growth may result in incorrect determinations of regeneration failure. Allow for a slow establishment period of 1-5 years for naturally regenerated stands. However early monitoring is still important if corrective management activities, like supplemental planting, are needed that take advantage of initial site preparation.

Density of seedling stands should be maintained between 600-1200 well distributed (i.e., at least 60% of area fully stocked) trees per acre (plantations 400-1200 trees per acre).

5.2 Intermediate Treatments

5.2.1 Release

Following establishment, jack pine seedlings and saplings can be outcompeted by other tree species resulting in jack pine mortality and reduced stocking and representation well into the poletimber stage. When aspen reproduces as an associate, it often assumes dominance. As site quality improves, aspen as well as other species (e.g. oak, white pine, red maple) can limit and out-compete jack pine.

In instances of aspen or other species competition, release operations will generally be required to control competition and maintain tree vigor. Release operations are best implemented before desirable stems are physically suppressed and while there are still many individuals to choose from. Seedlings and saplings generally respond to release with significant increases in vigor, height, and diameter growth. Release operations should be implemented early in the life of the stand, typically at 7-10 years of age. Release at an earlier or later stage will not have the same beneficial effect.

Weeding or cleaning operations are also sometimes recommended in overstocked jack pine seedling and sapling stands of more than 2000 trees per acres to prevent stagnation (8, 102). A northern Minnesota precommercial thinning study compared unthinned to thinned (4x4, 6x6, and 8x8 ft. spacings) plots and found after twenty-two years that average stand diameter increased 3.5 inches in DBH in the unthinned plots, and 4.1, 5.1, and 5.8 inches in DBH,

respectively, in the thinned plots (12). Sapling stands with a site index of 50 or less and stocked in excess of 2000 stems per acre should be thinned to 600-1200 stems per acre. Higher quality stands tend to self-thin through stem competition and natural suppression. Very dense stands, like those that sometimes originate from direct seeding or fire (i.e., >10,000 trees per acre), can be mechanically thinned by clearing strips about 8 feet wide and leaving strips 2 feet wide (8).

5.2.2 Thinning

Commercial thinning of jack pine is uncommon in the Lake States since many stands are primarily managed for pulpwood. Thinning in jack pine can however reduce the length of fiber rotations and increase sawtimber output (8, 100).

Thinning is an option on better quality sites (site index of 60 or greater) to increase production of poles and small sawlogs. Low or mechanical (plantations) thinning is generally recommended. Do not remove more than one-third of the stand basal area in any one thinning operation, as jack pine can be subject to wind and snow/ice damage. Refer to the stocking chart (Figure 33.21) to help determine timing and level of thinning. On less productive sites or in stands managed for fiber, thinning is not recommended (8).

5.3 Natural Regeneration Methods

Even-aged management is the generally accepted method to obtain jack pine regeneration. Natural jack pine regeneration methods generally require some form of soil scarification or disturbance for successful germination and seedling establishment. Artificial regeneration (seeding or planting) is also a generally accepted and commonly practiced method to establish jack pine. The even-aged natural regeneration methods generally accepted and supported by literature are:

- Clearcut
- Seed tree
- Shelterwood (Conditionally Recommended)

Table 33.6. Recommended and Conditionally Recommended natural regeneration methods. A detailed discussion of these methods can be found later in this chapter.

FOREST COVER TYPE	NATURAL REGENERATION METHODS							
	Coppice	Clearcut	Seed Tree	Overstory Removal	Shelterwood	Patch Selection	Group Selection	Single-tree Selection
Jack Pine	NR	R	R	R	CR	NR	NR	NR

R - Recommended
CR – Conditionally Recommended (see Regeneration Systems for more detail)
NR – Not Recommended

5.3.1 Even-Age Regeneration Methods

5.3.1.1 Clearcut (Recommended)

The clearcut method is an even-aged regeneration system designed to naturally regenerate a stand from seed by the removal of most or all woody vegetation during the harvest. Regeneration is from natural seeding from trees cut in the harvest operation, or in some cases, natural seeding from adjacent stands. Clearcutting is a recommended method for naturally regenerating jack pine stands at rotation (8).

An important aspect for the successful application of the clearcut method in jack pine is the presence of serotinous cones. Serotinous cones persist on the tree for years and result in an accumulation of seed within these unopened cones. The unopened cones provide the primary seed source after the harvest operation. In the Lake States however, stands may contain trees with non-serotinous or partially serotinous cones. Careful cone and seed assessment is needed prior to using this regeneration method to ensure that adequate seed will be available after the harvest. Direct seeding may need to be considered if the existing seed bank is limited (see Artificial Regeneration).

If the current tree quality is desirable and there is an ample number of serotinous cones, a new seedling stand can be established naturally by scattering cone-bearing slash on bare mineral soil seedbeds. The heat near the ground surface (18 inches and less) will open the cones and release seeds. The slash will provide light beneficial shade during germination to reduce moisture stress, but care is needed to avoid too much accumulation of slash that might interfere with later seedling development (8).

Proper scarification and seedbed preparation are critical for successful germination and seedling establishment. Mineral soil seedbeds provide the best conditions for seed germination because soil moisture levels are generally more stable and vegetation competition is minimized. Scarification can be accomplished by several methods and should be tailored to the particular stand conditions. See the following Scarification section for more detail.

In stands with limited numbers of serotinous cones along with non-serotinous and/or partially serotinous cones, the clearcut regeneration method may be modified by conducting scarification 2-3 years before the harvest to establish advance jack pine seedlings. This modification is similar to the shelterwood method; however some regeneration may also originate from the limited numbers of serotinous cones present in slash after the harvest. Complete the clearcut harvest after adequate advance regeneration becomes established, anticipating post-sale regeneration in addition to advance regeneration. Adequate jack pine stocking should be between 600-1200 seedlings per acre and at least 60% milacre stocking. The harvest can be done during winter months with at least one foot of snow cover to protect the advance regeneration.

5.3.1.2 Seedtree (Recommended)

Figure 33.17. Jack pine seed tree with prescribed fire on the Northern Highlands American Legion State Forest. Photo by WDNR.

The seed tree method is an even-aged regeneration system designed to encourage seed origin regeneration by leaving enough trees singly or in groups to naturally seed the area. This method is generally used in jack pine stands with serotinous cones and is coupled with prescribed fire to open the serotinous cones and prepare a favorable seedbed. Some managers have coupled the seed tree method with pre-harvest scarification in place of fire, however seed dispersal from the seed trees may be limited with this method if the cones are mostly serotinous. The seed tree method has been used effectively in the Lakes States but is less common likely due to the additional resources and preparation required, as well as the difficulties in achieving the appropriate timing and intensity of prescribed fire (65, 2).

The jack pine seed tree method should retain at least 10 well-distributed, quality seed trees per acre (8). A Superior National Forest study determined 7-9 seed trees per acre were adequate, however this study stressed the importance of careful seed tree selection: high quality trees with an abundant supply of serotinous cones. Trees with a DBH greater than 11 inches produced the most viable seed in this study (2). Managers in Wisconsin have generally retained higher numbers of seed trees (10-20 per acre), depending on the quantity and quality of cones within the seed tree crowns. Tree selection should also consider that average jack pine seed dispersal distances are approximately twice the height of the tree.

Prescribed fire is critical with this method to both prepare a suitable seedbed and open serotinous cones. The fire needs to limit slash amounts and reduce the humus layer to less than 0.2 inches, exposing mineral soil (21). Prescribed burns are generally conducted in spring, early summer, or fall. Backfires are most effective at reducing the humus layer and still sufficiently hot to open serotinous cones (2). Burns should take place soon after the harvest to minimize the risk of wind throw prior to seed dispersal (i.e., after one warm month of drying conditions). Jack pine seed trees often are scorched and killed by the fire. If seed trees survive beyond the regeneration period they can increase the risk of insect and disease problems. If conditions for seed germination are not favorable following seed dispersal, supplemental seeding or planting may be required (8). See the Prescribed Fire section for more detailed information on the use of fire in jack pine.

5.3.1.3 Scarification

Proper site scarification is a critical element to ensure successful regeneration of jack pine. Standard logging operations often result in a disturbed forest floor, however the level of disturbance is often inadequate to create favorable seedbeds for jack pine regeneration. Prescribed fire or mechanical scarification is often required to ensure successful germination of jack pine seed (22).

Jack pine stocking is directly related to the proportion of favorable seedbed that is available (88). Favorable seedbeds for jack pine germination include exposed mineral soil and a residual humus layer of 0.2 inches or less. Excessive post-harvest slash and/or organic duff layers greater than 0.5 inches can inhibit germination, although complete removal of the humus layer from the site can also have an adverse effect on seedbeds by decreasing nutrient availability, especially on dry nutrient poor sands. Some light slash cover is desirable to provide light shade, reducing surface temperatures and drying to improve germination. Undisturbed heavy mosses, lichens, sedge, and thick, poorly decomposed organic horizons make poor seedbeds for jack pine because they dry out quickly and do not allow for the upward movement of moisture, thereby limiting seed germination and seedling survival. (18, 81, 22). Seedbeds with some silt and clay content, as well as water tables within 6 feet of the surface, also improve germination success. Some upland outwash sands may be too dry at times for good germination. Sphagnum moss seedbeds over moist sands have been a notable exception where good germination without scarification has been noted. Best management practices for water quality and biomass harvesting guidelines are important considerations for all jack pine scarification operations (refer to Wisconsin’s Forestry Best Management Practices for Water Quality Field Manual and Wisconsin’s Forestland Woody Biomass Harvesting Guidelines).

A successfully prepared seedbed will have at least 40-60% exposed mineral soil. Mechanical scarification and prescribed fire have both been used to expose mineral soil for jack pine regeneration. Prescribed fire emulates the natural regeneration ecology of jack pine and has been used effectively to prepare seedbeds and open serotinous cones (see following Prescribed Fire section for more information). Mechanical scarification is often the preferred method because it offers flexibility, good quality control, and a seven- to eight-month window for operation, along with effective control of competing vegetation.

When mechanically preparing a seedbed for natural jack pine regeneration where aspen is present in the stand, limit soil disturbance around the individual aspen trees to minimize aspen sprouting.

Deep scarification to expose mineral soils may provide relatively good results on drier course-textured soils. However, on wetter sites with finer-textured soils, establishment may be best on seedbeds near the mineral soil-humus interface. Seed burial due to soil sloughing and duff, as well as flooding and cold temperatures on wetter sites, are common problems with deep scarification. (97, 22, 34). Soil sloughing can be minimized by allowing the scarification to settle prior to harvesting or seeding. Depending on the scarification method and soil type, allowing loose soils to stabilize may also help reduce air pockets and improve early seedling survival.

Mechanical scarification equipment for jack pine includes blades (straight, Salmon), anchor chains, roller choppers, root rakes, drags, disks, rotary-head scarifiers, disk trenchers, plows, and patch scarifiers (Bracke, Leno).

Straight/Salmon Blades and Root Rakes

Figure 33.18. Pre-harvest blade scarification. Photo by Douglas County Forestry Dept.

Blade and rake scarification are common and successful pre-harvest methods of soil scarification in mature jack pine stands that have enough room between the trees to maneuver equipment effectively. This type of scarification is often more effective than other methods in stands with a heavy oak, hazel, and/or sedge component. The equipment operator should try to expose as much mineral soil seedbed as possible (i.e., at least 40-60% recommended). With a straight blade, the equipment operator should angle the blade, just deep enough into the sod/duff layer to ensure good seedbed exposure. Straight blade scarification is usually done in 20-40 foot segments and at the end of each segment the operator lifts the blade while still pushing forward to roll the sod layer over, running the flap of sod over with the dozer tracks. This technique shakes the accumulated soil out of the sod layer, thus keeping the disturbed piles down to two feet or less in height. The operator should make sure that there is no soil accumulation around the base of trees to be harvested. Too much soil accumulation around the base of trees makes it difficult to operate logging processors during the harvest. Creating large soil and sod piles (sometimes 3-4 feet high) is the most common mistake made by inexperienced equipment operators, resulting in very difficult harvest conditions for the logging contractor. Salmon blades and root rakes contain teeth that are designed to turn and expose soil in place, minimizing the accumulation of large piles.

Anchor Chains

Drag scarification with anchor chains is a common and successful method to prepare jack pine seedbeds and distribute cone-bearing slash after a harvest. Anchor chain scarification should be done immediately after harvest with non-frozen soil conditions, preferably in late spring or summer, before serotinous cones open and disperse their seed. If done in early summer, it can help reduce competing vegetation more effectively through greater root disturbance. Roller chopping can be done prior to chaining to reduce competing vegetation, particularly in stands

with an aspen component. Jack pine slash must contain serotinous cones with viable seed to achieve successful natural regeneration (with the exception of shelterwood harvests that rely on seed rain from non-serotinous cones). Supplemental direct seeding can be done if the site does not have adequate cones. Anchor chaining is most effective on sites with a limited cover of sedge and other competing vegetation, as well as a limited humus layer. Previously dense jack pine stands with limited hardwood and brush competition that are dominated by light mosses over mineral soil are ideal. Slash should be adequately scattered during harvest operations to help distribute cones and promote the opening of serotinous cones by exposing them to the higher temperatures near the soil surface (i.e., slash heights of 18” or less). Scattering slash also allows the chains to reach the ground and not float up on heavy slash loads. Roller chopping can also be utilized to break up heavy slash loads and improve chaining effectiveness. The chain setup should consist of at least two chains spaced six feet apart, attached to a draw bar to keep them adequately separated. Adding bars on the chain ends in an “X” formation also helps keep the chains free of debris and helps limit floating up on slash. Bars or spikes should also be added to the chain links to increase scarification effectiveness. Two passes over the site at right angles will help maximize coverage and increase cone distribution; however, one pass may be sufficient on lighter slash. On formerly furrowed sites, chaining across the furrows effectively exposes more mineral soil seedbed. Rubber tire skidders are typically utilized to pull the chains but tracked dozers can be used if more power and equipment floatation are needed.

Figure 33.19. Anchor chain scarification. Photo by Vilas County Forestry Department.

Harvesting Operations

Whole tree ground skidding during non-frozen conditions may provide adequate scarification and mineral soil exposure. If natural regeneration is desired, the jack pine trees must be topped and the tops scattered before skidding to ensure as much of the seed source stays on site as possible.

5.3.1.4 Shelterwood (Conditionally Recommended)

Non-serotinous jack pines are more common along the southern edge of the species range and can be found in central and northwestern Wisconsin (87). The mature cones on these trees typically open and disperse seed in September to October. Common jack pine regeneration methods, like clearcutting, are not as successful in non-serotinous stands since there is inadequate seed within the harvest slash. The shelterwood method in combination with

scarification to expose mineral soil has been successfully used in stands with predominantly non-serotinous cones (8, 13, 63).

Regeneration is usually accomplished using a two-step shelterwood. The initial harvest (seed cut) should reduce stocking levels to 30-60 square feet of basal area per acre, leaving a uniform crown cover of vigorous, high quality trees (best phenotypes) with non-serotinous cones (8). The harvest operation may provide some scarification, but it is usually insufficient to produce a consistent mineral soil seedbed. Post-sale mechanical scarification (e.g., anchor chain or blade) is recommended to produce a seedbed better suited for jack pine germination (see scarification section), as well as control competing vegetation. Harvesting and scarification operations must be timed with a good cone crop (every 3-4 years). Michigan DNR has observed success using the shelterwood method on sites with a high summer water table (within 6 feet) and limited sedge competition (63). Complete the final harvest or overstory removal as soon as adequate advance regeneration becomes established, typically 2-3 years after the seed cut. Some have noted longer establishment periods up to 10 years, but the overstory should be removed as soon as possible after adequate regeneration is established to minimize seedling losses due to suppression and logging damage, and the risk of jack pine budworm buildup in the overstory and subsequent defoliation of the newly established seedlings (17). Ideally the overstory removal should be conducted with sufficient snow cover to minimize damage to the advance regeneration.

Disadvantages to the shelterwood method may include; increased timber sale establishment costs, longer regeneration period compared to clearcut and seed tree methods, mortality of overstory trees prior to the final harvest, and potential for conversion to more tolerant associated species (17, 63).

5.4 Artificial Regeneration Methods

Tree planting and direct seeding are successful and commonly utilized methods to establish jack pine regeneration in the Lake States. Chapter 22 provides guidelines for artificial regeneration and should be referenced when developing artificial regeneration prescriptions. Some jack pine specific considerations are also discussed here to aid in jack pine tree planting and direct seeding practices.

5.4.1 Planting

Some stand conditions are not conducive to natural jack pine regeneration or direct seeding (e.g., excessive competing vegetation, unfavorable seedbed conditions, limited cone-bearing slash, poor quality growing stock) and therefore tree planting may be a preferred management option. Tree planting also provides the opportunity to introduce well adapted seed sources and improved genetic material into stands. Jack pine specific planting considerations include:

- Tree planting densities for jack pine generally range between 400-1200 seedlings per acre, with 6-8 foot spacing typically recommended (9).
- Both bare root and containerized stock are successfully used for jack pine planting operations in Wisconsin. Managers need to consider site conditions, site preparation methods, seed source, planting operations, and costs to determine the appropriate

stock type. Chapter 22 provides detailed information on advantages and disadvantages of bare root and containerized stock types.

- One-year old bare root (1-0) or containerized jack pine stock is generally recommended for hand planting on sites with good site preparation and limited competing vegetation. Two-year old seedlings are generally recommended for sites with greater competition and where machine planting will be utilized.
- Bracke scarification, disk trenching or DNR fire plows are common tree planting site preparation methods used in Wisconsin. Herbicide treatments may be used alone or in combination with these mechanical methods to control heavy competing vegetation.
- Consider delayed reforestation of sites where weevils (i.e., Northern Pine and Pales) are present
- First year regeneration monitoring is important to determine if supplemental planting is needed to improve stocking levels. Supplemental planting should be conducted by the second or third growing season while site preparation is still adequate.

5.4.2 Direct Seeding

Jack pine sites are often well suited for direct seeding operations, as long as favorable seedbeds are available. Direct seeding can be used to supplement or replace natural seeding in stands with limited cone production, non-serotinous cones, or on other poorly regenerated areas where a seed source is not naturally present. Advantages of direct seeding jack pine include introduction of well adapted seed sources, low cost, simple and rapid application, and good seedling development. Direct seeding results however are often variable and careful consideration must be given to the following:

- As with natural seeding, favorable seedbeds are required for direct seeding success. See scarification section for more information on favorable seedbed conditions.
- Scarification can be accomplished by drags, blades, disks, spot scarifiers, trenchers, or prescribed fire, with seed distributed by hand (cyclone seeder, coffee can), machine (Bracke, seed bombs), or aerial. Depending on scarification method, equipment, labor, and seed availability, sites may be spot or broadcast seeded.
- Seedbeds should be allowed time to stabilize prior to seeding.
- Seeding rates should be 20-30,000 repellent-treated, viable seeds per acre (average 131,000 seeds per pound). Seeding rates greater than 30,000 seeds per acre generally do not enhance stocking (88). In application, sowing rates are commonly 4-6 ounces per acre. Greater aerial coverage can be achieved if seeded in two directions; 2-3oz. per acre in each direction.
- Jack pine seed from Wisconsin DNR state nurseries is generally repellent-treated, using the fungicide thiram, which is also an animal repellent, and a latex paint carrier. Refer to the seed treatment SDS for more information on personal protection equipment to use while handling treated seed.
- Establishment is generally greatest when seeding is done from late winter to mid-June. Broadcast seeding is best over fresh snow or before snow melt in early spring. Sowing during this period minimizes the interval between seeding and germination, reducing the risk of seed loss to predators. Soil moisture is usually plentiful in spring due to snow melt and warming soil temperatures encourage good root development (35, 22).

- Allow at least 3-4 growing seasons before judging direct seeding results. Delayed germination can result in increases in stocking between the first and third years after sowing (88, 94). Reseeding can be successful if a favorable seedbed remains.
- Avoid direct seeding in areas with heavy competing vegetation, such as aspen, or on higher quality sites (i.e., dry mesic habitat types) where competition may limit results, unless herbicides are utilized.
- Aerial seeding can be an effective regeneration method for jack pine, as long as adequate amounts of favorable seedbed are available. Aerial seeding coverage is maximized in larger block stands of at least 25 acres in size and by limiting the number of reserve trees that may interfere with aerial applications. Islands of reserve trees interfere less with aerial applications than dispersed tree retention.

5.4.3 Seed Source Considerations

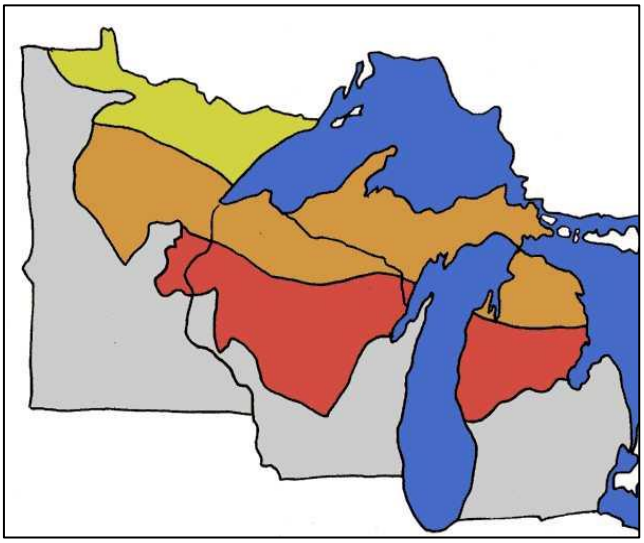


Figure 33.20. Seed zone map developed from the twenty-year results of the Lake States jack pine seed source study (45). Seed sources kept within each zone should generally perform best (i.e., each color represents a separate seed zone).

Jack pine is known for its wide genetic variation in many important characteristics, such as height growth, form, disease resistance, cone serotiny, and others. Lake States provenance studies have found that local seed sources generally grow better than the average for all provenances, but sources moved slightly northward generally grow best (93, 46). Provenance study results have been used to develop seed zone maps to guide the appropriate movement of jack pine seed sources in the Lake States (Figure 33.20)(46). Tree improvement efforts by the Division of Forestry and other agencies continue to develop jack pine seed orchards through advanced progeny testing and breeding.

Selecting appropriate seed sources is critical for maintaining stand productivity. Managers need to consider seed source appropriateness when selecting material for both tree planting and direct seeding practices. Jack pine plantations on suitable sites that exhibit poor growth and form may have originated from inappropriate seed sources and should not be naturally regenerated, but rather reforested with genetically better adapted trees.

5.5 Rotation Lengths and Cutting Cycles

In even-aged silvicultural systems the rotation is defined as the period between regeneration establishment and final cutting. The length of rotation may be based on many criteria including culmination of mean annual increment, mean size, age, attainment of particular minimum physical or value growth rate, stand history, and biological condition.

Commonly the lower end of the rotation length range is defined by the age at which maximization or culmination of mean annual increment (MAI) growth occurs. The upper end of the rotation length range would be defined by the average stand life expectancy. However, very little objective data exists identifying these endpoints in general and even less by site type. In addition, growth and mortality rates vary among stands and can be affected by many variables, including site characteristics, silvics, stocking, silvicultural methods, insect and disease, and units of measure. The rotation ages provided are based on general data, literature, empirical evidence, and professional experience. In application, foresters will need to regularly review stands in the field and exercise professional judgment concerning tree vigor and mortality and stand growth and productivity. On all sites, individual trees and stands may maintain vigor longer or decline earlier than these rotation length guidelines.

Recommended Rotation Ages

- 40 to 70 years is recommended for timber management
    - Fiber production is generally 40 to 60 years on most sites.
    - Sawtimber production is generally 60 to 70 years on better quality sites with site indices of 60 or greater.

- Extended rotation is not recommended for this short-lived, early successional species. However, vigorous stands and vigorous individual trees on good sites could potentially be managed to 80-100 years.
- Short rotations of less than 40 years are generally not recommended in order to maintain soil nutrient levels, especially on dry nutrient poor sandy soils with whole tree harvesting operations. Refer to Wisconsin's Forestland Woody Biomass Harvesting Guidelines for more information on dry nutrient poor sandy soils and rotation age considerations (10).

The decision to rotate stands at the lower end of the rotation length range or earlier can be based on many conditions, including very nutrient poor sites, landscape level management modifications, site competition factors, jack pine budworm defoliation, disease outbreaks, and low vigor. Documenting the site and stand conditions are important when determining a rotation age for a stand.

Different rotation lengths can result in increased production of some benefits and reduced production of others. Landowner goals and objectives will also influence rotation age determination. See the discussions under management considerations in the following sections to evaluate some benefits and costs (ecological, economic, social, and cultural) associated with different forest management strategies.

5.6 Other Silvicultural Considerations

5.6.1 Cover Type Conversion

Jack pine can be difficult to maintain on all but very dry and nutrient poor habitat types. Jack pine ecosystems are dependent on fire or logging for regeneration and in the absence of these disturbances oak, white pine, and red maple often become more abundant if a seed source is available. From an ecological and forest diversity standpoint, it may be desirable to maintain

the jack pine cover type, since the acres and volume of jack pine growing stock have been steadily decreasing in Wisconsin (64). In some cases it may also be possible to manage for stands of mixed species composition. Depending on site capabilities and landowner objectives, however, conversion to other associated species may be prescribed. For example, conversion to red pine on the dry to dry mesic habitat types has been common because of the species' economic value and increased growth potential on these sites. However, jack pine may perform better than red pine on very dry to dry habitat types in terms of average height growth and survival (67, 93). Conversion to red pine and other closed canopy forest on the state's Pine Barrens, woodlands, and savanna habitats has raised concerns over loss of diversity and fragmentation of these ecosystems at the landscape level (39, 40).

Conversion will be simplest in mixed stands with adequate stocking of desirable associated species, where the jack pine can be removed through periodic thinning or overstory removal. Some common associated species that may be considered in conversion include aspen, oak, white pine, red pine, red maple, balsam fir, and white spruce. If adequate stocking of desirable species is not present, artificial conversion would be required through site preparation and planting. The following are management considerations for common jack pine natural conversions:

- Aspen – 10-30 ft^2 of basal area per acre of healthy aspen trees required for coppice regeneration to produce adequate stocking. Consideration should be given on very dry and wet-mesic habitat types, where aspen conversion may not be recommended due to poor productivity, except for wildlife purposes (53).
- Oak – Clearcut/coppice regeneration methods may encourage a mixed conifer-deciduous type for greater diversity. Jack pine – oak mixed stands can be successfully managed on very dry to dry habitat types where oak are regenerated easily by advanced regeneration/coppice and inclusions of jack pine are regenerated by creating suitable jack pine seedbed conditions. See Chapter 41 for guidelines on evaluating oak regeneration potential from advance regeneration and sprouting.
- Red and White Pine – Stocking of at least 400 seedlings/saplings per acre or sufficient overstory of red or white pine to facilitate shelterwood regeneration methods.

Refer to the individual species cover type chapters for more information on natural conversion.

5.6.2 Prescribed Fire

Many of today's jack pine stands resulted directly from wildfires of the past. These stands can provide insight into the use of fire for effective management and regeneration of the species (30). The use of prescribed fire as a tool in the management of jack pine has been relatively uncommon in the Lake States (30), due in part to the logistical challenges of safely burning in the pine fuel type. Its applications include seedbed preparation, fire hazard reduction, control of competing vegetation, insect and disease control, and Pine Barrens restoration. Prescribed fire can be an economical alternative to either mechanical or chemical site preparation (2, 30, 76, 91).

Jack pine is well suited for the use of prescribed fire because of a number of adaptations to fire including delayed seed release from serotinous cones, early reproductive maturity, fast growth rates in full sun, and preference for mineral soil seedbeds (15). Temperatures ranging between

120 and 140 degrees Fahrenheit are required to melt the resin on the cones, open the scales and release the seed (91). Heat does not markedly affect seed viability, however if cones ignite, the seed will be destroyed (15).

Most research indicates the best use of prescribed fire for jack pine is in site preparation for regeneration (94). Regeneration methods commonly used in conjunction with fire include tree planting, direct seeding, and seed tree. Note that prescribed fire in clearcut slash (i.e., without seed trees) does not usually result in adequate natural seeding, because most of the cones within the slash ignite, destroying this source of seed.

Prescribed fire for jack pine regeneration is most often used to create a favorable seedbed for germination. The most receptive seedbeds for germination are on exposed mineral soil consisting of minor amounts of post-harvest slash and a thin residual humus layer of 0.2 inches or less. Excessive post-harvest slash can shade seedbeds and organic duff layers greater than 0.5 inch in depth can inhibit germination and adversely affect establishment (7, 15, 21, 91, 94). However, complete removal of the humus layer can also have an adverse effect on seedbeds. Several case studies cited that maintaining some humus will increase nutrient availability and promote moisture retention by slowing runoff (2, 30, 76).

Planning the timing and intensity of prescribed fires is important in achieving the desired results. Multiple research trials have indicated the most effective time to burn for seedbed preparation is either spring or early summer, with both advantages and disadvantages listed below (2, 7, 91). Alternatively, early fall has been suggested as a potential burn season to disperse seed for germination the following spring, but more field evaluation in Wisconsin is likely needed (7, 63).

<u>Spring Burns</u>
Advantages:

- Most favorable time for seed germination and establishment
- Lower humidity, higher burning index

Disadvantages:

- Control of the fire can be difficult
- Operational times limited – number of days when fire weather is appropriate to burn.
- Due to higher forest floor moisture levels spring fires may not burn with enough intensity to consume organic duff layers, resulting in limited exposure of mineral soil seedbeds.

<u>Early Summer Burns</u>
Advantages:

- Drier fuel conditions result in a hotter burn and greater likelihood of reducing organic duff layers, resulting in greater exposure of mineral soil seedbeds.
- High humidity levels make fire control easier
- Better control of competing vegetation

Disadvantages:

- Establishment may be too late in the year for seedling survival

- Newly germinated seedlings are more vulnerable to heat and desiccation during drier summer months

Burning should be conducted as soon as possible after the timber harvest and after at least one warm month of drying conditions have lapsed. This ensures that fuels have adequately cured and if regeneration is to be conducted using the seed tree method, the loss of trees to wind throw will be minimized (7). Refer to the section on seed tree regeneration for more details. Other considerations regarding timing include:

- Conduct burns after mid-day when RH is lowest and winds most stable (2).
- Strive to burn when there is a high Buildup Index (moisture deficiency in fuels) and a low Burning Index (current burning conditions). This will permit maximum fuel consumption including duff with minimal control difficulty. This is considered the most important factor in removing enough of the humus layer to prepare a receptive seedbed (30).

In addition to timing, a fire must burn with sufficient intensity to ensure enough heat is generated to eliminate excessive slash, reduce the humus layer, control competing vegetation and open cones. Fuels should be cured, and uniformly distributed over 75% of the ground area. The humus layer must be dry to within 1 inch of the mineral soil. Based on previous Lake States' guidance, adequate fuel loads to ensure a hot fire are normally obtained if the pre-harvest condition of the stand contains a minimum of 100 $ft^2$of basal area per acre and achieves a minimum slash depth of 18 inches (7).

The ignition pattern chosen will also influence fire intensity. The two primary ignition patterns include headfires and backing fires. Headfires are hot, rapidly moving fires that consume slash quickly, and open serotinous cones. However, because they move rapidly, they may be harder to control and may not adequately consume enough of the humus layer as is required. In contrast, backing fires consistently consume the required amount of humus because fires burn significantly slower and longer in duration at higher temperatures, typically producing sufficient heat to open serotinous cones on seed trees as well. In addition, since these fires burn more slowly, they are easier to control (2). In either case, when burning in conjunction with a seed tree regeneration method, individual crown torching will normally not result in cone ignition because the higher temperatures are unlikely to last more than several minutes (15).

Prescribed fire has been used with varying degrees of success in controlling undesirable competition and reducing insect and disease concerns. Competition from both sedges and hazel can inhibit regeneration and subsequent establishment. Fire can temporarily impede these competitors and allow for jack pine seedlings to grow above the recovering grass and shrub layer (2, 91). However, to be effective a prescribed fire must be conducted either before or immediately after the overstory has been removed. A hot early to mid-summer burn will be most effective at limiting competing brush species, especially if the litter fuels have been adequately cured (2, 15). For example, single spring prescribed fires have been shown to have little lasting impact on hazel competition, but summer fires more effectively decrease hazel vigor and sprouting (11).

In addition to controlling competition, fire can also help to protect jack pine from pests, including damping-off fungi, *Scleroderris* canker, dwarf mistletoe (*Arceuthobium* spp.), and *Ips pini*. Elimination of newly created slash will discourage population outbreaks from *Ips* beetle (91).

Additional considerations when using prescribed fire include:

- Larger burn areas are more cost effective to administer.
- Timber harvest plans should incorporate road design that will also serve as future firebreaks.
- Harvest plans should also incorporate treatment of slash to aid in facilitating suitable burning conditions – directional felling of trees and uniform slash distribution and depth.

Monitoring and documenting prescribed fire trials is recommended during pre- and post-burn application. The intent is to assess and document fire effects on seedbed enhancement, regeneration stocking, competition, and fire conditions. Recommendations for monitoring include:

- Document pre-burn and post-burn forest conditions – density, size and vigor of regeneration, and competition
- Measure fire conditions – fuel load, fire intensity/flame length, rate of spread
- Document costs associated with the burn – equipment time and labor
- Examine the site 2-5 years post-burn – document density, size and vigor of regeneration, and competition. If the objective of the prescribed fire is for regeneration from jack pine seed, its success may not be evident for two to five years post-burn. Survival of germinants depends upon a number of factors including a good seedbed, adequate moisture, seed supply, delayed germination, seed predation and rate of recovery of competitive species.

8 APPENDICES

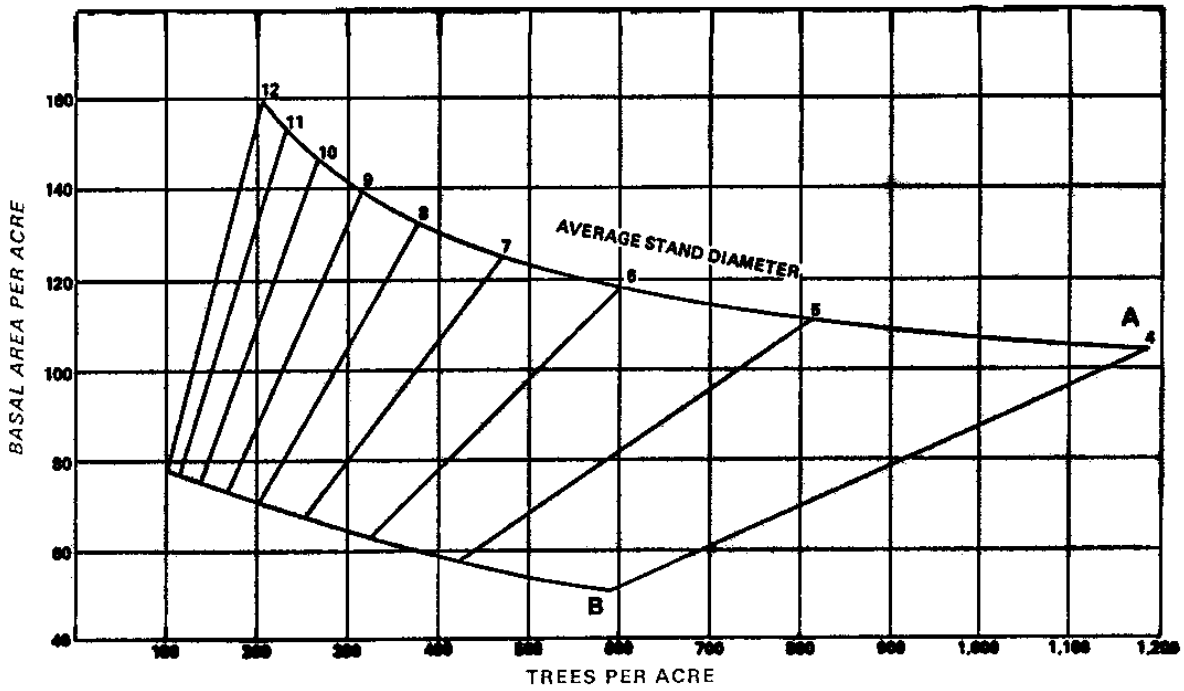
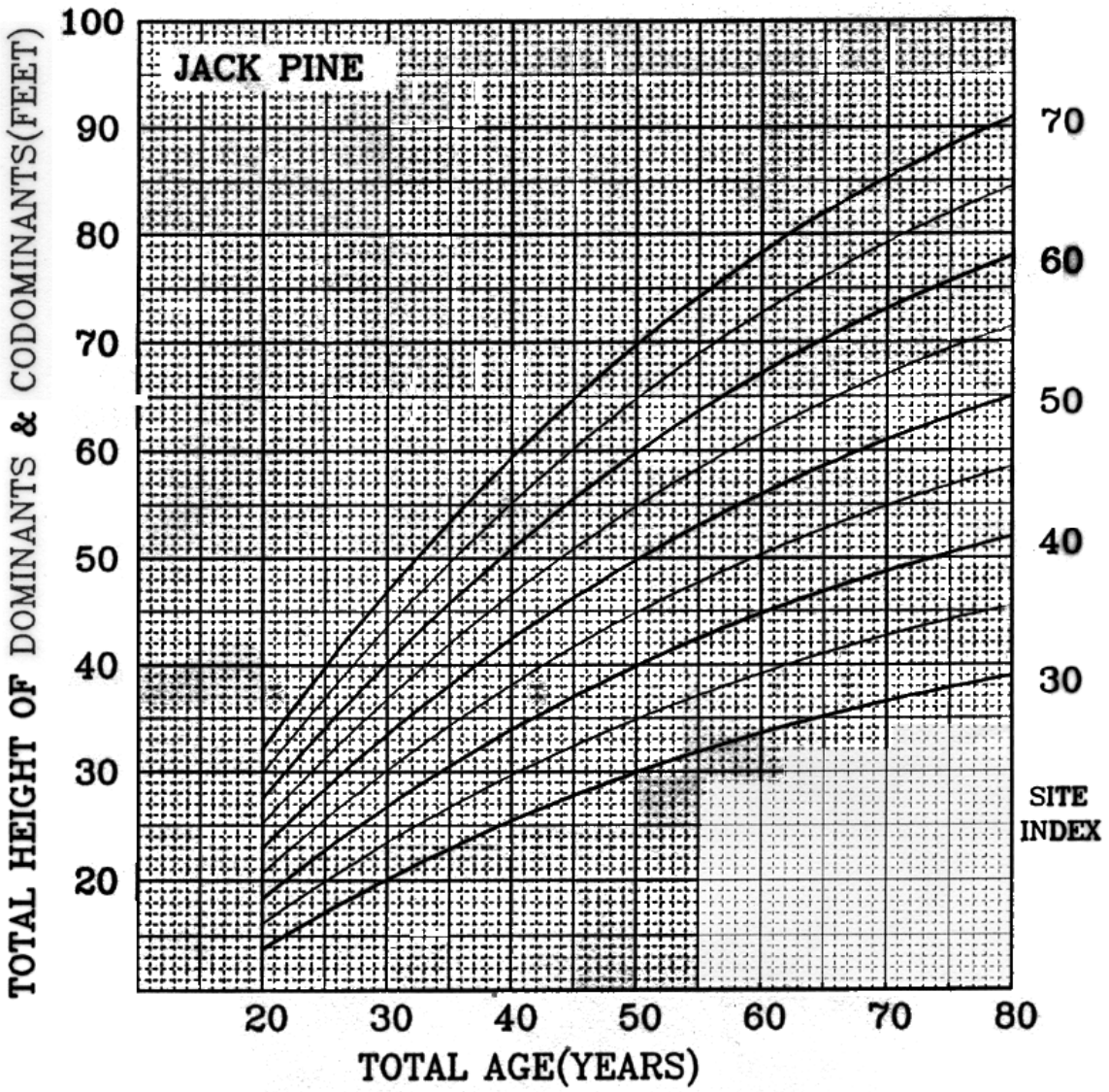


Figure 33.21. Stocking chart for jack pine stands (8).

Recommended upper limit (A-curve) is based on stand tables from Eyre and LeBarron (31) and adjusted to approximately 85 percent stocking for pole timber and 100 percent stocking for sawtimber stands. Minimum stocking (B-curve) is based on crown width for open-grown trees.



Jack pine (Gevorkiantz 1956c, derived from Wackerman *et al.* 1929, and from Eyre and LeBarron 1944)
Lake States
Number of plots and number of dominant and codominant trees not given
Total height and total age, anamorphic, equation not given
Convert d.b.h. age to total age by adding years according to site index (BH = 0.0):

SI:	30	40	50	60	70	80	90
Years:	9	8	7	6	5	4	4

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	1.6330	1.0000	-0.0223	1.2419	0.0000	0.99	0.50	1.1
SI	0.6124	1.0000	-0.0223	-1.2419	0.0000	0.99	0.50	1.1

Figure 33.22. Site index curves for jack pine in the Lake States (16).

8.1 Forest Health Guidelines - Forest Health Protection (FHP)

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
DEFOLIATING INSECTS	
MOTHS **Jack pine budworm –** *Choristoneura pinus* Caterpillars from May to July. Outbreaks occur approximately every ten years and last two to four years. One heavy defoliation event causes 10-15% top kill and 5% mortality. Two heavy defoliation events cause 45-50% top kill and 20-25% mortality. Damage is most severe on poor quality sites. Stand history of defoliation events may also impact seed production and the supply of stored seed in serotinous cones.	• Do not hold stands on poor quality sites past maturity. Keep stands even aged and regenerate by appropriate regeneration methods. • Maintain basal area between 70-110 ft²/acre. Avoid widely spaced trees that produce large crowns with numerous male flowers and overstocked stands with suppressed trees. • Stand size is critical. Promote age class diversity to avoid large areas of mature and overmature trees that are all susceptible at the same time. Stands should be at least 40 acres and boundaries designed to minimize edge. • **Do not leave strips or islands of jack pine during harvesting.** • Salvage stands with severe defoliation. • Consult a forest health specialist if considering insecticide treatments to determine the economic feasibility of spraying.
Northern conifer tussock moth - *Dasychira plagiata* Overwintering larvae emerge in April and initially feed on male cones and previous year's needles. Older caterpillars move to current year's needles until pupation occurs in July. Adults emerge and lay eggs mid-summer. The next generation of larvae hatch and feed for approximately 10 days in August before overwintering under bark scales. Severe defoliation for two consecutive years has killed entire stands. Caterpillars prefer jack pine but will attack red pine under 30 years old. The last outbreak of this insect occurred in Douglas, Bayfield and Burnett Counties in the 1960s.	• Do not hold stands on poor quality sites past maturity. Keep stands even aged and regenerate by appropriate regeneration methods. • Avoid large areas of susceptible trees. Townships with greater than 40% jack pine or stands larger than 1 section may contribute to large outbreaks. • Salvage stands with severe defoliation. • Consult a forest health specialist if considering insecticide treatments to determine the economic feasibility of spraying.
Eastern pine elfin - *Callophrys niphon* Caterpillars from May to June. Typically feed on trees less than 23 ft. in height. Young larvae feed on new foliage. Older caterpillars may eat old needles.	• No control is necessary.
Washed-out zale - *Zale metatoides* Caterpillars from July to August.	
Gray spring zale - *Zale submediana* Caterpillars in June.	
Abstruse looper - *Syngrapha abstruse* Caterpillars from May to June.	
Pine pinion - *Lithophane lepida* Caterpillars from June to July.	

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
MOTHS: NEEDLE MINERS **Pine needleminer -** *Exoteleia pinifoliella* Attacks pole sized trees. Consumes old needles first, then new. **Pine needle sheathminer -** *Zelleria haimbachi* Hollows out terminal needles at the base, typically near male flowers.	• Control is rarely necessary. • If severe damage occurs, consider a salvage harvest.
MOTHS: SILK NEST BUIILDERS **Pine webworm -** *Pococera robustella* Colonies build silk tubes and feed on nearby needles. Occasional pest of seedlings or saplings.	• Control is rarely necessary as natural enemies typically keep populations in check. • If control is necessary it should be conducted while nests are small. Either remove nests by hand (crush or drown caterpillars in water) or spray branch tips in mid-June and again in early July.
SAWFLIES: SILK NEST BUIILDERS **Pine false webworm -** *Acantholyda erythrocephala* Live singly or in small colonies in silk nests up to 6 inches long. **Nesting-pine sawfly -** *Acantholyda zappei* Larvae build silk tubes where they feed on chewed off needles.	
SAWFLIES **Abbott's sawfly -** *Neodiprion abbottii* Larvae from June to July. Larvae feed in colonies during early instars then individually in later instars.	• Accept damage and monitor for population increases. • Allow control by natural enemies and disease. • Kill small groups of larvae by hand. • If control is necessary, spot treat small groups of larvae with pesticide, or broadcast treat large infestations. Success will be greater if larvae are treated when they are small. • Keep stands fully stocked and promote early canopy closure by planting 800 or more trees per acre.
Brownheaded jack pine sawfly - *Neodiprion dubiosus* Larvae from June to July. Larvae feed in colonies and prefer edge trees.	
European pine sawfly - *Neodiprion sertifer* Larvae from May to June. Larvae feed in colonies on old needles.	
Introduced pine sawfly - *Diprion similis* Larvae from May to September. Larvae feed in colonies during early instars then individually in later instars on old needles. Prefer ornamental, nursery, and plantation trees.	
Jack pine sawfly - *Neodiprion pratti banksianae* Larvae from May to June. Larvae feed on old needles in colonies and prefer open grown, even-aged stands of all ages.	
Redheaded jack pine sawfly - *Neodiprion rugifrons* Larvae from June to September. Larvae feed on old needles in colonies. When a second generation occurs new foliage is also eaten.	
Redheaded pine sawfly - *Neodiprion lecontei* Larvae from June to September. Larvae feed in colonies and prefer edge trees less than 20 feet tall. Larvae consume old needles first, then new.	
Red pine sawfly - *Neodiprion nanulus nanulus* Larvae from May to June. Larvae feed in colonies on old needles.	
Swaine jack pine sawfly - *Neodiprion swainei* Larvae from July to August. Larvae feed in colonies mostly on old needles.	

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
BEETLES **Pine chafer -** *Anomala oblivia* Adults feed in June and July preferentially on new needles. Pine chafers eat the sides of needles through the sheaths causing the needles to turn brown and droop.	• Allow control by natural enemies. • If control is necessary, apply insecticide in late June.
SUCKING INSECTS	
Scale insects and aphids Heavy infestations cause needle yellowing, premature foliage drop, and dieback of twigs and branches. These insects also produce honeydew which can lead to growth of sooty mold. Three common species are: **Black pineleaf scale -** *Nuculaspis californica* Infestations are usually confined to a cluster of stressed trees. **Pine needle scale -** *Chionaspis pinifoliae* **Pine tortoise scale -** *Toumeyella numismaticum* Pest in sapling and pole-sized plantations.	• Usually controls are not needed and not realistic. • Maintain stand vigor. • Promote early stand closure. • If control is necessary, treat scales with horticultural oil before budbreak or spray crawlers with insecticide in June or July. • Kill mound ants protecting the scales.
Saratoga Spittlebug - *Aphrophora saratogensis* Feeding causes twig flagging, reduced tree growth, stem deformity, and branch mortality. Prefers red pine under 15 feet tall. Severe infestations may cause significant mortality.	• Remove alternate hosts of Saratoga spittlebug (sweet fern, young willow, berry bushes, etc.) when they occupy 20% or more of the ground cover. • Consult a forest health specialist about the feasibility of treatment with insecticides.
Pine spittlebug - *Aphrophora cribrata* Heavy infestations (typically localized) cause branch flagging starting with new growth and progressing to the trunk, typically from the bottom of the tree up. Prefer saplings and pole-sized trees.	• Natural enemies, including a parasitic fungus, usually keep populations in check. • If insecticides are necessary, apply in July when 95% of spittle masses are empty.
PINE PITCH MIDGES **Gouty pitch midge -** *Cecidomyia piniinopis* Larvae feed in small resin filled pits between the needles on new growth. May kill needles and shoots on trees 4-16 feet tall. Two other common species are *Cecidomyia banksianae* which feed in resin filled cavities close to buds and *Cecidomyia reeksi* which feed in resin masses typically on open-grown saplings.	• Control is rarely necessary because populations are usually kept in check by natural enemies.
BARK AND WOOD INSECTS	
BARK BEETLES *Ips* spp. Tunneling in inner bark causes mortality in sapling to sawlog sized trees, singly or in pockets. Weakened or storm-damaged trees, trees that have been struck by lightning, and overmature or overstocked stands provide a breeding ground for the beetles. Mortality is usually limited to a few trees during years of normal rainfall. However, during dry summers with suitable breeding material, beetle populations quickly build up and cause large scale mortality.	• Use the pine species and spacing intervals best suited to the site. • When cutting during the growing season, remove harvested timber from the stand within 3 weeks of cutting. • If cutting stands adjacent to other pine stands during the growing season, utilize tops down to a 2” diameter. Leave branches attached to stem wood to speed drying. • Avoid overmature stands. • Promptly salvage or destroy potential breeding material, such as pines that are

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
	severely damaged by wind, lightning, fire, disease, insects, or other destructive agents. • If trees have low vigor due to drought, defoliation, or disease, consider a pre-salvage harvest. • Harvest newly infested and adjacent trees before the following spring to reduce local populations.
Mountain Pine Beetle - *Dendroctonus ponderosea* Mountain pine beetle (MPB) outbreaks occur regularly in lodgepole and other pines in Western North America but do not currently occur in Wisconsin. The recent, successful establishment of MPB in jack pine in Alberta, Canada however could allow spread through the range of jack pine to the eastern U.S. (28).	• Management guidelines are currently only available for MPB's host trees in western North America. Contact forest health staff immediately if you suspect a MPB infestation in Wisconsin.
Red Turpentine Beetle - *Dendroctonus valens* Tunneling under bark causes mortality in weakened trees of pole size and larger. Adult beetles attack dead or weak trees as well as fresh stumps, freshly cut logs, and exposed damaged roots. Although infestation by this insect itself is usually not serious, it vectors *Leptographium* fungi. Look for red boring dust and pitch tubes on the bottom six feet of attacked trees.	• Control is typically not necessary or feasible.
Pine Shoot Beetle - *Tomicus piniperda* Adult beetles feed on and kill the central portion of the lateral shoots. Attacked shoots turn red, droop, then fall to the ground. This insect is under federal quarantine as of 2015 but removal of the quarantine is being evaluated.	• Follow quarantine rules: this insect is native in Eurasia and North Africa and was first discovered in North America in 1992. All of WI, MN, and MI are quarantined. • Cut trees so stumps are as low to the ground as possible.
Jack pine tip beetle - *Conophthorus banksianae* Causes shoot tip mortality mostly of saplings. Attacked shoot tips turn red, droop, then fall to the ground. The pine flower snout beetle *Cimberis elongata* sometimes attacks buds and shoots in association with Jack pine tip beetle.	• Control is rarely necessary.
LONGHORNED BEETLES **Whitespotted sawyer -** *Monochamus scutellatus scutellatus* Attack dead and dying trees. Larvae feed beneath the bark and bore deep into the wood. Adults feed on the bark of twigs and may cause flagging.	• Avoid stacks of logs on landings from late June through August when possible. If cutting during the growing season, remove harvested timber from the stand within 3 weeks of cutting. • Cover logs with slash 1-2 feet thick. • Pile logs in the shade of standing trees. • Peel or immerse logs in water. • Allow control by natural enemies.
WEEVILS **Northern Pine Weevil -** *Pissodes approximatus* Severe feeding damage by the adults may kill some shoots.	• Delay planting seedlings for 2 years after harvesting pines. • Remove freshly cut pine stumps before planting seedlings (rarely practical). • Treat freshly cut stumps with an insecticide (rarely practical).

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
Pales weevil - *Hylobius pales* Infestations girdle and kill seedlings and damage the young shoots of older trees.	• Delay planting seedlings for 2 years after harvesting pines. • Remove freshly cut pine stumps before planting seedlings (rarely practical). • Treat freshly cut stumps with an insecticide (rarely practical).
White pine weevil - *Pissodes strobi* Feed inside the leader of sapling to pole-sized trees causing the leader to die and often resulting in lateral branches assuming dominance. Look for leaders that curl into a shepherd's crook and die.	• In existing infestations, local population and damage can be reduced by removing and destroying infested terminals before new adults emerge in mid-July. • In plantations and open grown seedling/sapling stands: In open areas, plant 900 - 1,000 trees per acre in mixed or pure plantations and maintain at least 700 trees per acre until the canopy closes. • Accept stem deformity. • If control is necessary, apply insecticidal application to prevent attack by adult beetles.
Pine root collar weevil - *Hylobius radicis* Typically attack sapling and small pole-sized trees. Damage may cause trees to tilt or break off at the root collar. Trees planted on nutrient-deficient, sandy soils, planted too deeply or spaced too widely are most vulnerable to attack. The insect is a known vector of Leptographium fungi.	• On sandy soils, plant with root collar no more than one inch deep. • Encourage early crown closure by planting 800 or more trees per acre and increase the seedling survival rate by controlling weeds and rodents for 5 years after planting. • Avoid planting within one mile of infested Scotch pine stands or liquidate nearby Scotch pine.
Pine root tip weevil - *Hylobius assimilis* Feeding on roots causes flagging, top kill and tree mortality in pole-size pines. Moderate weevil damage reduces tree growth. Stands on nutrient-deficient, sandy soil and those near Scotch pine are more vulnerable to weevil attacks.	• Liquidate nearby Scotch pine. • Do not plant jack pine and red pine together if the site index is 50 or below – keep it to one species or the other.
SCARAB BEETLES **White Grubs -** *Phyllophaga* spp. Feeding on roots kills 1-3 year old seedlings. Damage is most severe in sandy soils and on grassy or weedy sites. White grub densities above 0.2 per square foot may cause heavy seedling mortality and stunting of surviving seedlings.	• Survey stands for white grubs before planting. If the population density is high, delay planting for one to two years. • Consult a forest health specialist for current insecticide options.
MOTHS **Eastern pine shoot borer -** *Eucosoma gloriola* Open-grown trees are most susceptible to damage within 10 years of establishment. Larvae attack shoots in May and June causing them to turn red, droop, and then fall to the ground. Leaders and lateral shoots near the tops of trees are typically attacked.	• Control is rarely necessary or feasible.
Zimmerman pine moth - *Dioryctria zimmermani* Attack and feed in the base of shoots or branches or in eastern gall rust galls. Attacked branches flag and may	• Control is rarely necessary or feasible.

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
break off. Damage causes white, irregular pitch blisters at the site of attack.	
Northern pitch twig moth - *Retinia albicapitana* Prefer to attack open grown saplings at the crotch of multiple twigs. Damage causes hollow, thin-walled, brownish pitch blisters. Two other closely related species, *Petrova houseri* and *Petrova pallipennis*, cause similar damage.	• Control is rarely necessary or feasible.
FOLIAGE DISEASES	
Pine Needle Rust – *Coleosporium asterum* The fungus requires an alternate host (aster, goldenrod) to complete its life cycle. Occasionally it causes needle loss on the lower 5 feet of branches during spring. The disease is most prevalent on trees up to sapling size. Defoliation may cause growth reduction, although mortality is uncommon.	• Control is rarely necessary. • Do not plant seedlings at overly dense spacing. • Remove alternate hosts of the fungus (aster, goldenrod) within 1000 ft. of jack pines manually or by applying herbicides before August when spores are released.
Brown Spot Needle Blight - *Mycosphaerella dearnessii* The fungus initially causes brown bands with yellowish margins on needles. Infected needles turn brown and prematurely fall in late spring or early summer.	• Control is rarely necessary. • Do not plant seedlings at overly dense spacing.
Tar spot needle cast – *Davisomycella ampla* Infects current year needles. Lesions become apparent by the following spring. Severe infection leads to browning and premature casting of year-old foliage.	• Control is rarely necessary.
SHOOT DISEASES/ CANKERS	
Diplodia Shoot Blight - *Diplodia pinea* Current year's shoots become stunted with short, brown needles. Cankers on branches cause branch flagging and dieback. Severe canker development and subsequent branch dieback are occasionally observed after a hail storm. The fungus also attacks seedling root collars causing mortality.	• Remove infected overstory and windbreak pines. • If more than 50% of the crowns are affected consider a salvage harvest. .
Sirococcus Shoot Blight - *Sirococcus conigenus* Current year's shoots droop or become stunted and die. The fungus causes shoot dieback and stem and branch cankers on the current year's growth. A single year of infection may kill seedlings and repeated infections may kill saplings.	• Remove infected overstory and windbreak pines.
Scleroderris Canker - *Gremmeniella abietina* Infected needles turn orange at the base in spring and later turn brown and fall off. The fungus moves to branches and main stems where cankers develop. Cankers girdle and kill seedlings and small trees. Damage is minor on trees over 6 feet tall. Lower branch mortality of larger trees occurs in frost pockets.	• Avoid planting in frost pockets. • Salvage infected pines.
CANKER ROTS	
Red Ring Rot - *Phellinus pini* The fungus causes a white pocket rot in the trunk of infected trees. The fruiting bodies often appear at branch stubs or knots. They are annual or perennial,	• Control is rarely necessary.

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses and Control Alternatives
hard, and bracket or hoof shape with irregular margins. Upper surface is dark grayish to dark brown.	
GALL DISEASES	
Eastern Gall Rust (pine-oak gall rust) - *Cronartium quercuum f. sp. banksianae* **Western Gall Rust (pine-pine gall rust)** - *Peridermium harknessii* Eastern gall rust requires red oaks as alternate hosts to complete its life cycle and is considered to be widespread in Wisconsin. Western gall rust infects pine without an alternate host. Based on the survey in the 1960's, the distribution of western gall rust is limited to north-central Wisconsin (Vilas, Oneida, and Lincoln Counties). The fungus causes swollen spherical galls on pine twigs, branches and main stems. Main stem galls may cause breakage at the point of the gall. Galls kill seedlings and branches of older trees. The disease is very common on jack pine near oaks.	• Examine seedlings for galls or swelling on main stems, branches, and root collar areas before planting. Do not plant symptomatic seedlings.
ROOT DISEASES	
Armillaria Root Disease (Shoestring root rot) – *Armillaria* spp. Girdles roots and lower trunks, causing cankers as well as stringy white rot. Affected trees have reduced growth and chlorotic needles. Dieback and mortality can occur, especially during drought years or following two or more years of defoliation (all ages). White mycelial fans and dark-colored rhizomorphs can be found in the cambial zone. *Armillaria* spp. produce fall mushrooms.	• Do not hold stands on poor quality sites past maturity. • Harvest declining stands before bark beetle infestation, mortality, and decay take place.
Annosum Root Rot - *Heterobasidion irregulare* Jack pine are susceptible to infection by *Heterobasidion irregulare* mainly through spores landing on freshly cut stumps as for other pines. Infection could spread to living jack pines if their roots contacted old infected roots. Annosum root rot causes pockets of trees to develop thin crowns, reduced growth, and tree mortality. Pockets expand at about ½ to 1 chain every 10 – 15 years. Fruiting bodies develop at the base of infected trees and stumps. Early fruiting bodies are white and look like popcorn. Under favorable conditions, fruiting bodies develop into perennial bracket-shaped conks.	Management • Expect tree mortality in pockets and growth loss in trees around the pocket margin. • Harvest healthy trees before harvesting diseased trees. • Leave the bottom 8 feet of infected trees on site to avoid inadvertent disease spread. • Clean logging equipment with pressurized water before leaving diseased stands. Prevention • Apply a registered fungicide on fresh cut stumps as soon as possible after cutting or by the end of each day.
ABIOTIC DAMAGE	
Drought, fire, wind and other abiotic factors may kill or significantly stress impacted trees.	• Pre-salvage or salvage dead or stressed trees to avoid insect and disease issues. Trees with more than 50% of the canopy affected are unlikely to recover and should be harvested.

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