Chapter 32

Red Pine Cover Type

WISCONSIN
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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
Red pine (*Pinus resinosa*) comprises 50% or more of the basal area in sawtimber and poletimber stands, or 50% or more of the stems in sapling and seedling stands. In mixed pine stands, red pine is predominant.

Associated Species
Many red pine stands are fairly pure with few associates. Pure natural stands typically originate following catastrophic fire. Red pine plantations often are established as monocultures. The most common associate within the red pine cover type is white pine (*Pinus strobus*). Other major associates are jack pine (*Pinus banksiana*), aspen (*Populus* spp.), and oak (*Quercus* spp.).

1.2 Silvical Characteristics[1]

Red pine is a native species adapted to a disturbance regime characterized by periodic ground fires and infrequent crown fires. It most commonly occurs on dry sands in historically fire-prone landscapes.

Red pine is considered genetically uniform, exhibiting relatively limited genetic variation throughout its geographic range.

Flowering and Fruiting
Red pine is monoecious; female flowers are borne mostly in the middle third of the crown (in the upper third of the crown in older trees), and the purple male flowers are borne in the lower crown. Flowers are borne April to June, and pollination occurs May to June. Fertilization occurs in July the following year when cone growth is completed, and the fully developed seed coats have hardened. Cones are about 0.5 inches long by late summer of the first year, and about 1.5-2 inches long when growth is completed. Cones are completely brown when they ripen late summer to early fall of the second year.

Seed Production and Dissemination
Good seed crops are produced every 3-7 years, with bumper crops only every 10-12 years. Seed production can be reduced by prolonged rainy weather at the time of . Almost complete cone crop failure can occur due to insects, extreme weather, and other damaging agents between the first and second year of development. Cone production is stimulated by high temperatures during the spring and summer two years before cone maturation. The production of cones can be most prolific on branches that are thick, long, and young, and on the south side of the tree. Cone production per tree generally improves as stand density decreases; thinning can help increase cone production per tree.

[1] Mainly from Rudolph (1990).

Seed dispersal begins when the cones ripen. Cones open best on hot, still autumn days when there is little wind to carry the seeds far. During the first month, the heaviest most viable seeds fall. Most seeds are dispersed between September and November, but seed dispersal can continue throughout the winter and into the following summer. Most seeds fall to the ground within 40 feet but can be disseminated up to 900 feet from the parent tree.

Seedling Development

The ideal seedbed to facilitate germination is bare mineral soil, but light pine litter is acceptable. Germination occurs spring to early summer and requires adequate moisture and warm temperatures (mostly 70-86^{o}F). Factors facilitating the maintenance of moist seed include finer textured soils (e.g., loamy sand), thin moss, water table within 4 feet of the surface, light cover over the seed, and some shade. Germination can occur under dense brush, in heavy sod or litter, and in heavy ash, but seedlings generally do not develop or grow well. Other conditions known to inhibit germination include soil pH ≥8.5 and full sunlight for ≥4 hours per day. Both germination and early seedling survival are hindered by summer drought and high surface soil temperatures.

Growth and Development

Red pine is shade intolerant. Seedlings can become established with 35% full sun and grow well under 45% of full sun until age 5. Established seedlings grow best in (near) full sunlight, if other requirements are met. Red pine seedlings grow slowly, usually requiring 4-10 years to reach breast height. Height growth usually increases once seedlings/saplings are 5-10 years old, and dominance in dense stands is often expressed by age 12. Radial growth is related to precipitation in the current season.

During the first summer following germination, seedlings develop a taproot usually 6-18 inches long. After the first year, lateral root growth tends to be greater than vertical growth. A water table within four feet of the soil surface along with a loose soil encourages early rooting depth. The uptake of soil moisture and mineral nutrients is improved by the formation of symbiotic mycorrhizae on seedling roots.

Most root elongation occurs in the spring and early summer. Root systems typically are moderately deep and wide spreading. Vertical roots (taproot and sinkers) typically descend 5-15 feet. Lateral roots mostly occur within 4-18 inches of the surface and can extend up to 40 feet beyond the crown (depending on competition from neighboring trees). Root grafts among neighboring red pine trees older than 15 years are common. Thinning apparently stimulates grafting. Grafting among trees can enhance tree health and wind firmness, but can also transmit damaging agents, including annosum. Soil conditions, including moisture, temperature, texture, and density, can influence the timing, intensity, and pattern of root growth. Root systems become stunted in poorly drained soils and some dense soils (e.g. hardpan and compacted soils).

Red pine trees often grow to 70-80 feet tall, and up to 36 inches dbh. Maximum size is nearly 150 feet tall and 60 inches dbh. Height growth rate is strongly influenced by site quality. Other factors that can impact height growth are overhead shade and damage to terminal growth (e.g.

insects). The rate of height growth tends to decrease as trees get older, and often becomes negligible as trees approach 150 years old. Diameter growth rates tend to be the greatest in vigorous, dominant trees with large, well developed crowns. Crown size and diameter growth are strongly influenced by stand density. Basal area growth rates range from <1 to >8 square feet per acre per year, but most commonly range 2-5 ft^2/ac/yr. Factors influencing variability in basal area growth include site quality, stand age, and density extremes (<60 and >200 ft^2/ac). Greatest growth rates generally are demonstrated by young stands on good sites, and slowest growth rates by old stands on poor sites.

Table 32.1. Summary of selected silvical characteristics.

Red pine (*Pinus resinosa*)	
Flowers	Monoecious. Flowers appear between April and June.
Pollination and Fertilization	Pollination by wind, during May to June. Fertilization occurs in July of the second year (1 year following pollination).
Cone Development and Maturation	Cones are about 0.5 inches long by late summer of the first year. Cones are about 1.5-2 inches long and completely brown when they ripen mid-August to October of the second year.
No. of seeds/lb	Seeds are light. Cleaned seed averages about 52,000/lb.
Seed Dispersal	Mostly September to November. Most seeds fall to the ground within 40 feet but can be disseminated up to 900 feet from the parent tree.
Good Seed Years	Every 3 to 7 years. Bumper crop every 10 to 12 years.
Seed Bearing Age	Best production 50 to 150 years.
Cone Production	Range 0-725 cones/tree.
Seed Viability	14-86%, usually best during good or better seed years.
Germination	Epigeal. Spring to early summer. Moist spring and summer essential to germination and establishment.
Seedbed Requirements	Mineral soil preferred.
Vegetative Reproduction	None.
Seedling development	Moist spring and summer essential to germination and establishment. 35% of full sunlight satisfactory for establishment, >45% full sunlight maximizes early growth, and near full sunlight maximizes growth once established.
Shade Tolerance	Intolerant.
Maximum Tree Longevity	Expected lifespan approximately 200 years. Maximum lifespan 350-400 years.

Red pine is a long-lived species. Individual trees can reach 350-400 years of age. Fully stocked stands can persist for at least 200 years, but may exhibit declining tree vigor, increasing mortality rates, and declining stand yield.

2 MANAGEMENT GOALS, LANDOWNER OBJECTIVES

Stand management objectives should be identified in accordance with landowner property goals, and within a sustainable forest management framework which gives consideration to a variety of goals within the local and regional landscape. The silvicultural systems described herein are designed to maximize tree vigor and stand growth to facilitate optimized productivity (quantity and quality) of a variety of timber products (e.g. sawtimber, pulpwood, utility poles, and cabin logs). 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

The red pine forest type provides significant economic and social benefits, but there are concerns about the ecological effects of red pine plantation management at landscape and regional scales. Past management has led to altered ecological complexity through development of single cohort, monotypic stands; decrease in older age classes; lack of within stand structural variability; interruption of natural processes; and placement on the landscape, fragmenting other systems. Landscape considerations for red pine are intended to address some of the ecological effects by recognizing management strategies that can be incorporated into management plans and prescriptions.

3.1.1 Historical Context

When the General Land Office (GLO) Public Lands Surveys (PLS) were conducted in Wisconsin (1832-1866), forests of white and red pine comprised about 2 million acres (Frelich, 1995); this represented about 9% of forest vegetation, making white pine – red pine the third most abundant forest type. Species composition and successional stage varied depending on soil type and disturbance regime. Red pine was historically a component of the northern dry forest, present along with white and jack pine, and northern dry mesic forest, existing with white pine, red maple, red oak, birch and aspen (Curtis, 1959). The most extensive blocks of white pine – red pine dominated forest were in Vilas and Oneida counties (WDNR 1995). Figure 32.1 displays red pine occurrence from the PLS; red pine forests were most abundant in the sandy landscapes of northwest, northcentral, northeast and central sands areas of the state. Within the Great Lakes region both Michigan and Minnesota contained considerably more pine forests than Wisconsin (Frelich 1995).

Red pine dominated forests mostly occurred within dry, sandy landscapes where fire was the principle disturbance agent; severe blowdowns occurred infrequently. Severe fires causing mortality of most overstory trees and initiating red pine stand development typically occurred every 100-250 years (return interval); both old and young stands could be decimated by catastrophic fires. As stand development progressed, highly irregular (frequency, severity, pattern) periodic surface fires altered understory composition and structure, and sometimes caused mortality of scattered individuals or groups/patches of overstory trees. Older trees often were well represented as patches, groups, and individuals. Age class structure within forest patches ranged from mostly even-aged to complex uneven-aged distributions.

Large pines were especially sought after early in the Euro-settlement period. By the late 1800s, the red and white pine forests were being removed at the rate of 3.4 billion board feet per year. (Curtis 1959). The pine slash burned easily and intense fires spread over large areas for several decades until the fire suppression program was developed. Much of the pine forest converted to aspen-birch and oak following the Cutover (WDNR 2005) or eventually was planted.

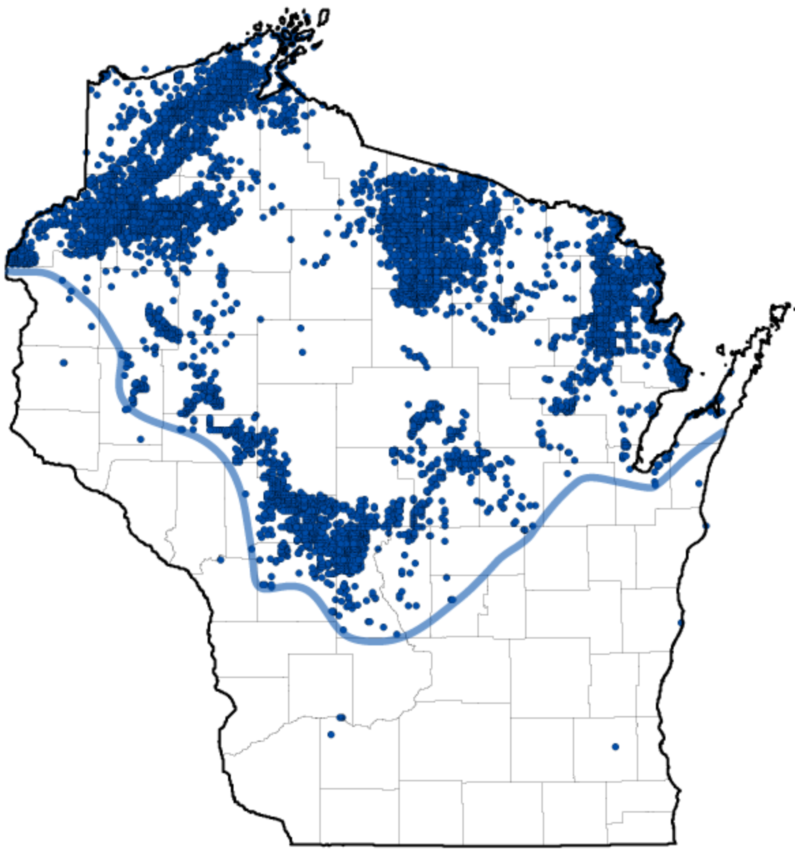


Figure 32.1. Map of red pine distribution from the GLO PLS data. A general range line for red pine in Wisconsin in the mid-1800's has been estimated and inserted to delimit the common occurrence of red pine; community outliers did sporadically occur beyond these range limits.

3.1.2 Current Context

Red pine is a common cover type, occurring on 4% of forest land in Wisconsin. Most stands are 1-60 years old and of plantation origin. Some of Wisconsin's existing red pine resource was planted on areas devoid of trees, often tax reverted agricultural land, during the 1930s by the Civilian Conservation Corps. On dry sites, where red pine is often cultivated, stands of jack pine, aspen, and oak are sometimes harvested and converted to red pine. The FIA records show that the red pine cover type has been increasing while jack pine has been decreasing since 1983 (Figure 32.2). Between 1983 and 2006 red pine acreage increased from 478,200 acres to 686,167 acres, an increase of 207,967 acres. However, jack pine acres have decreased about 191,000 acres during the same period. Management decisions to convert some jack pine stands to red pine were because of insect/disease issues, particularly jack pine budworm infestations. In some cases, jack pine stands have converted to oak or aspen. On richer, dry-mesic to mesic sites, mixed hardwood stands (e.g. oak, maple) are sometimes converted to red pine plantations. Currently, red pine is often planted as part of afforestation projects to reestablish trees on fallow agricultural lands.

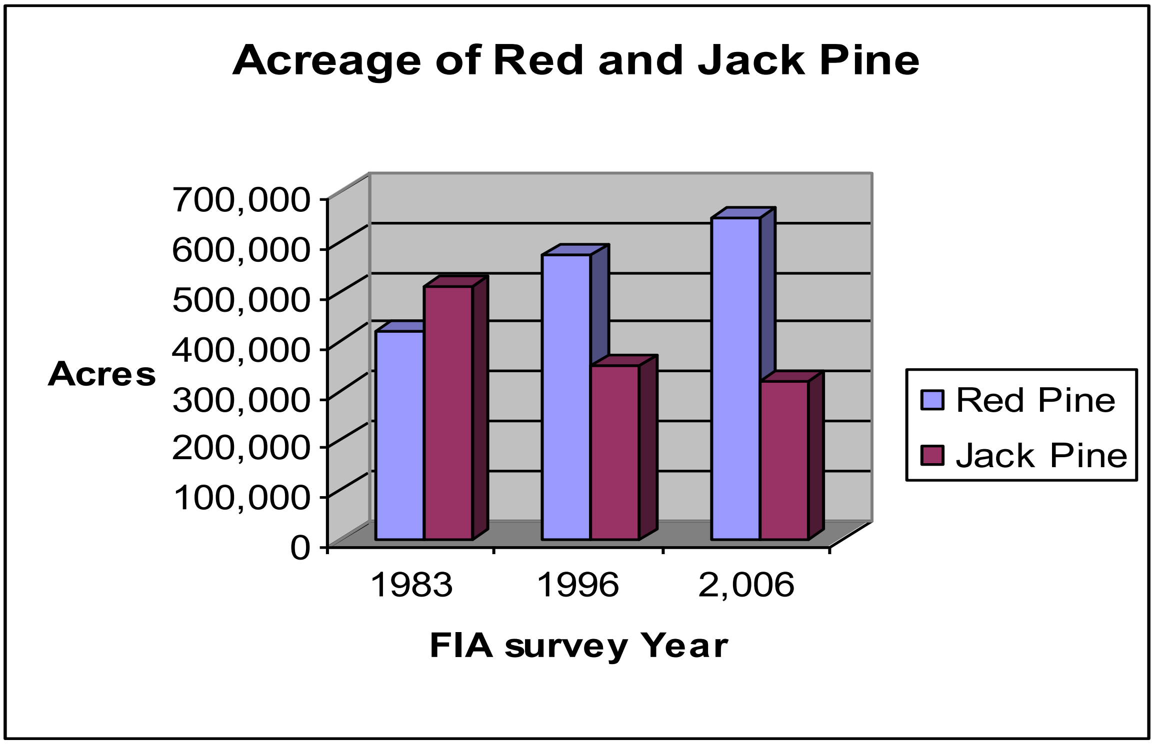


Figure 32.2. Acreage of red pine and jack pine over 3 FIA inventory periods, 1983-2006.

Most stands of red pine in Wisconsin are even-aged plantations from 1-60 years old (Figure 32.3). Some older stands from 80-100 years old also occur. Although red pine is a long-lived native species, there are few current stands that are older than 100 years. Older trees and stands provide unique ecological and social benefits but are poorly represented within modern forest landscapes.

Table 32.2 shows the distribution of red pine acreage by ecological landscape (EL) and stand origin (plantation or natural) based on FIA data from 2007 and Figure 32.4 displays a map of natural and plantation red pine in Wisconsin. Of the 697,000 acres of red pine, there were 143,000 acres that were apparently natural stands, and the vast majority, 554,000 acres, were plantations. Of the 14 Els listed in the table, the Northwest Sands had the largest acreage of red pine forests. Eight ELs contained significant red pine acreage. Nearly half of the natural origin red pine acres occurred in two ELs – the Northwest Sands and the Northern Highland.

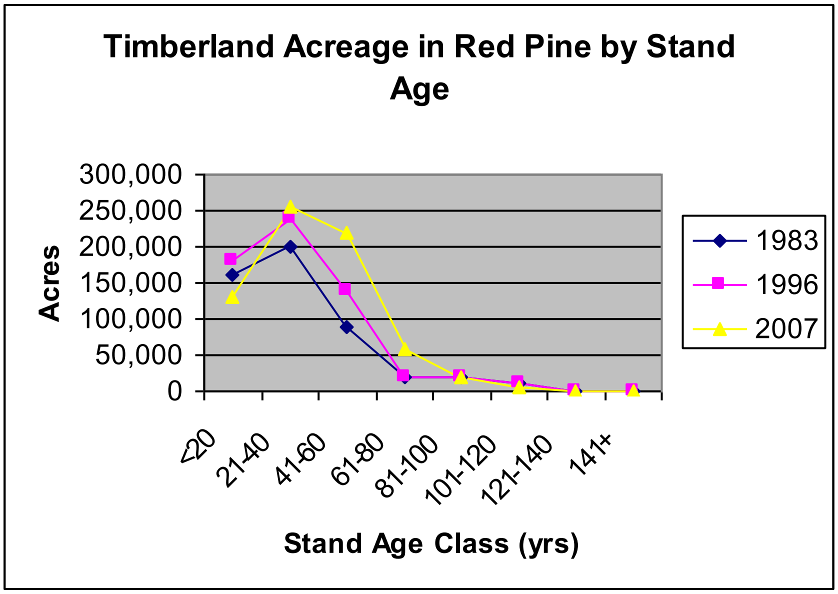


Figure 32.3. Forest age-class distribution for the red pine forest type in Wisconsin, over 3 FIA inventory periods, 1983-2006.

Table 32.2. Red pine – acres of forestland by ecological landscape and stand origin with sampling error (acreages with over 25% error are shaded) (data from FIA 2007).

	Acreage of timberland			Sampling error		
	Natural	**Plantation**	**Total**	**Natural**	**Plantation**	**Total**
Northwest Sands	34,854	88,363	123,217	12%	8%	7%
Central Sand Plains	12,310	97,133	109,444	21%	7%	7%
North Central Forest	17,936	70,339	88,275	17%	9%	8%
Forest Transition	10,314	68,269	78,583	22%	9%	8%
Northern Highland	30,219	37,835	68,053	13%	12%	9%
Central Sand Hills	5,668	60,773	66,440	30%	9%	9%
Northeast Sands	12,735	47,414	60,149	20%	10%	9%
Western Coulees and Ridges	7,413	40,782	48,195	26%	11%	10%
Northern Lake Michigan Coastal	2,540	13,770	16,311	45%	19%	18%
Western Prairie	564	11,520	12,084	96%	21%	21%
Superior Coastal Plain	4,200	6,332	10,533	35%	29%	22%
Southeast Glacial Plains	967	7,717	8,685	73%	26%	24%
Northwest Lowlands	3,175	3,175	6,349	40%	40%	29%
Central Lake Michigan Coastal		212	212	-	157%	157%
Grand Total	**142,895**	**553,634**	**696,528**	6%	3%	3%

Natural stands of red pine are uncommon. Severely altered fire regimes and stand developmental processes have forestalled natural regeneration processes. Historically, fire severity, timing, and pattern significantly influenced red pine regeneration processes across landscapes. Reductions in the frequency, extent, and variability of ground fires have been shown to change dominant successional pathways (Frelich and Reich 1995), influencing understory compositional and structural development.

A few old-growth patches are extant, and there are several relict stands that show no evidence of past harvest. Where found, these are small, and typically mixed with white pine and various hardwoods. Many of these also have not experienced fire for over a century, thus understory composition is increasingly dominated by hardwoods and shrubs rather than natural red and white pine regeneration.

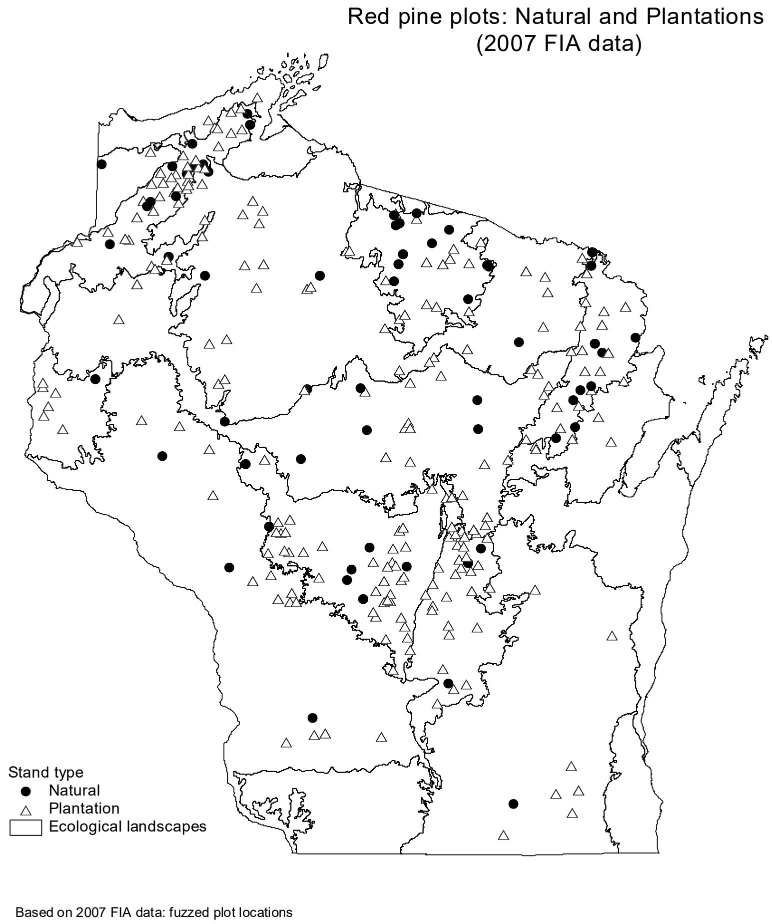


Figure 32.4. Map of red pine plantations and natural stands from FIA 2007.

3.1.4 Forest Simplification

Forest simplification refers to a reduction of species diversity and structural diversity. Human disturbances (e.g. fire suppression, fire ignition, tree cutting, artificial regeneration, and land conversion) have simplified the composition and structure of red pine forests and altered processes compared to historic conditions (Palik and Zasada, 2003). Management systems that manipulate vegetation and natural processes to encourage natural regeneration are rarely applied. Practices that cause simplification in red pine forests include:

- Application of standardized, homogenized management regimes (disturbance practices), including planting, thinning, and even-aged rotations
- Maintenance of single species, single cohort (even-aged) plantations
- Maintenance of relatively young stands lacking complex structural development
- Harvesting of the majority of older and old-growth stands
- Fire suppression

3.1.5 Landscape Pattern

Wisconsin's forested landscapes are made up of patches of different land uses, forest types, and age classes. The relative abundance and spatial arrangement of different patches forms a "landscape pattern" that can affect species' productivity, metapopulation dynamics, and ecological processes. A landscape made up of natural forest cover often has fewer and larger patches, with subtle and gradual transitional areas between them. Management for red pine can alter this pattern, creating patches of contrasting composition and structure that are typically smaller with abrupt boundaries. This change in landscape pattern breaks up a block of contiguous forest habitat and negatively affects landscape connectivity. Species that are area-sensitive (more likely to thrive in larger forest patches) or disturbance-sensitive may not find suitable habitat in a landscape that contains multiple blocks of red pine, particularly if rotations are short. Plant and animal dispersal mechanisms can be affected if species or their propagules have difficulty crossing or circumventing the red pine block, cannot find suitable habitat within it, or do not compete successfully with species that may be attracted to red pine or to the disturbance associated with an even-aged rotation.

3.1.6 Incorporating Ecological Complexity into Management

Ecological complexity in forest stands refers to compositional, structural, and functional variability across space and time. Variability can be interpreted at different scales; the range of natural variability can provide a realistic benchmark.

Prior to Euro-American settlement, variable natural processes guided the development of red pine forests and resulted in a range of conditions from relatively simple, homogeneous stands to very complex compositional and structural patterns. Currently, managed red pine stands by comparison tend to be relatively homogeneous and simplified. To increase diversity within and among red pine stands, management techniques need to be variable. Management practices and ecological conditions that could enable increased ecological complexity and benefits include:

- Develop and maintain large trees, cavity trees, snags, and coarse woody debris to provide structural diversity and habitat. These structures can be developed in current stands and can provide biological legacies at stand rotation (see Chapter 24). Retention of patches (aggregate retention) can provide unique structure.
- Improve species diversity. Create and manage some gaps within the stand during intermediate treatments and at rotation/regeneration; gaps can be managed using artificial regeneration, natural regeneration, or maintained as openings. Retain other species during intermediate treatments. Retain other species at rotation, especially white pine, to serve as seed sources. When establishing plantations, include other species.

- Apply variable density thinning (VDT). In traditional red pine prescriptions, stands are thinned uniformly. In contrast, most unmanaged forests have varying stand density and size. To emulate the natural variation, foresters can apply different thinning regimes throughout the stand, i.e. some areas heavily thinned and some lightly thinned (Franklin et al. 2007).
- Reintroduce fire. Ground fires can influence understory composition and structure and stand successional and developmental processes. Prescribed surface fire in older (>50 years old) red pine stands can be an effective management tool for eliminating shrub and hardwood competition, reducing thick duff layers, and preparing mineral seedbeds.
- Apply natural regeneration practices (see section on natural regeneration under Management Alternatives).
- Develop and maintain older forests across landscapes. Extended rotations offer the opportunity to produce significant timber yields while also producing other social and ecological benefits. Managed old growth focuses on unique ecological benefits. Maintain old-growth and relict stands; they are very rare.

3.1.7 Summary of Landscape Considerations

When deciding whether to actively manage for red pine, assuming the Habitat Type is suitable, consider the following factors:

- Evaluate landscape composition and structure, including species composition; successional and developmental stage; age structure; stand/patch size; type, intensity, and pattern of fragmentation; habitat diversity; NTMB populations and habitat needs; and common/uncommon management techniques.
- Apply landscape scale management by recognizing appropriate placement/location of red pine species in the landscape and the variety, age and size of stands.
- Match stand boundaries with large-scale, enduring physiographic and edaphic features not the present age structure or species
- Encourage connectivity of forest patches where it is possible to coalesce adjacent red pine stands.
- Promote species diversity within stands during planting, intermediate treatments, and rotation.
- Maintain reserve trees and increase structural diversity within stands through the development and maintenance of supercanopy trees, large trees, large cavity trees, large snags, and coarse woody debris.
- Increase structural diversity within stands through variable density management. Consider the development of gaps and patches of different ages and composition.
- Apply extended rotation and managed old-growth techniques.
- Protect old-growth and relict stands.
- Apply natural regeneration methods and prescribed fire.

3.2 Site and Stand Considerations

3.2.1 Soils

The red pine cover type is most common on dry (excessively to somewhat excessively drained), nutrient poor to medium sands in historically fire-prone landscapes dominated by sandy outwash, lacustrine, or washed till deposits. Productivity can be good to excellent on many of these soils, but is only fair on the driest, most nutrient poor sands. Examples of soil characteristics that improve productivity (increase moisture and nutrient availability) are finer textures (loamy sands), the presence of finer textured lenses or layers, underlying deposits (e.g. sand outwash over sandy loam till), and the presence of a water table at a depth of 4-9 feet. Red pine stands also occur on moist (moderately well to somewhat poorly drained) sands; productivity is generally good (to excellent) but decreases as soils become wetter.

Red pine plantations have been managed successfully on well drained to somewhat poorly drained loams and clays. On these moister and richer soils, natural stands sometimes occurred (historically) within landscapes where the fire regime was conducive to the regeneration and maintenance of red pine. Well drained (sandy) loams offer the greatest potential productivity.

Red pine generally does not grow well where the surface soil is alkaline (pH >6.5).

Red pine stands generally do not survive and grow on poorly drained soils.

Red pine occurs on a relatively wide range of soil types, with textures that include sand, loamy sand, and sandy loam. In some cases, red pine has been planted on heavier soils, including loams and clays. Because red pine typically grows on sandy sites, soil compaction is less of a management concern than in most other forest types. Soil displacement on roads and skid trails can be a concern in red pine stands, particularly for the sandiest sites. When the mat of ground vegetation is removed or worn away, bare mineral soil is exposed, and new vegetation is often slow to establish. Erosion by wind and water can keep these areas open, and bank slumping can prevent roadcuts from stabilizing; these impacts make parts of the stand non-productive. Roads and other travel routes have been implicated in the spread of non-native invasive plants. They can also act as barriers to the movement of some species, create habitat fragmentation and edge, and attract continuing human disturbances that prevent revegetation. Use travel routes and landing areas designed to meet the needs of the harvest while minimizing the portion of the stand impacted and maintain the ground vegetation mat wherever possible. As a general rule, less than 15 percent of a harvest area should be devoted to haul roads, skid trails, and landings (WDNR 2003).

Another area of concern for red pine sites is the potential for nutrient depletion over repeated rotations. Sites accrue nutrients through mineral weathering and atmospheric deposition. Nutrients can be lost from a site through leaching, volatilization (in the case of nitrogen), and removals in harvested wood. If losses are greater than inputs over the course of a rotation, nutrient depletion occurs. If losses are relatively small and the site is “rich”, or has a large amount of nutrient capital, then concerns are minimal. However, if the site is sandy and has little nutrient capital, losses may be significant. There is uncertainty in predicting the exact amount of potential nutrient losses, and more research is needed in this area.

Tree species vary in the amount of nutrients they take up, and a large proportion of nutrients are held in the small branches, twigs, and foliage. Perala and Alban (1982) studied nutrient removals in red pine for two sites at Pike Bay, MN (**Error! Not a valid bookmark self-reference.**). These red pine plantations were on two different soil types. One soil was a Warba very fine sandy loam with sandy clay loam at a 24-inch depth, and calcareous at 41 inches. The other was an unnamed soil, dominantly loamy fine sand with clay loam and sandy clay loam between 33 and 43 inches, underlain by sand. The red pine stands were 39 and 41 years old, respectively. Compared with other tree species in this study, red pine had a lower nutrient demand than trembling aspen and white spruce, but a higher nutrient demand than jack pine. Nutrient uptake was greater on the richer site.

Table 32.3. Nutrient content of red pine foliage, branches, bark, and bole wood, for two soil types in Minnesota.

Nutrient content of red pine components, lb/ac (Perala and Alban, 1982)						
Foliage	*Branches (includes dead)*	*Bole bark*	*Bole wood*	*Bole wood + bark*	*Above-ground total*	*Soil type*
Nitrogen (lbs/acre)						
117	56	39	105	145	318	Warba vfsl, calcareous
98	31	37	95	132	261	lfs, scl, s
Phosphorus (lbs/acre)						
16.7	7.2	6.0	8.3	14.3	38.2	Warba vfsl, calcareous
11.2	3.8	5.0	7.4	12.4	27.4	lfs, scl, s
Potassium (lbs/acre)						
53	29	15	63	78	161	Warba vfsl, calcareous
53	17	18	40	58	127	lfs, scl, s
Calcium (lbs/acre)						
37	60	65	107	172	269	Warba vfsl, calcareous
29	46	62	105	168	244	lfs, scl, s
Magnesium (lbs/acre)						
12.8	8.3	7.8	24.1	31.8	53.0	Warba vfsl, calcareous
10.3	6.3	8.4	21.2	29.6	46.2	lfs, scl, s

Potassium (K) appears to be a mineral nutrient of concern for red pine. Nutrient balances for a rotation can be estimated by subtracting harvest removals from atmospheric and mineral weathering inputs. An estimate of the amount of K inputs from atmospheric deposition on average sites is 0.36 lbs/acre/year, based on data from the five Wisconsin stations of the National Atmospheric Deposition Program (NADP), for the time period 1997-2006. Mineral weathering inputs of K on average sites are estimated at 1.5 lbs/acre/year, and on nutrient-poor sites at 0.7 lbs/acre/year (Kolka et al., 1996).

Estimates of biomass and K removals for thinnings and final harvest of a 120-year old plantation are shown in Table 32.4. Inputs over 120 years are estimated to total 223 lbs K per acre on average sites, and 127 lbs K per acre on nutrient-poor sites. Removals of bole and bark wood, with 5% green tree retention at final harvest, represent 139 lbs K per acre. In this case, given uncertainty in the estimates, inputs of K over the rotation are approximately equal to harvest removals on nutrient-poor sites. However, if 80% of foliage and branches were also removed at each thinning, with 5% green tree retention at final harvest, another 243 lbs K per acre would be removed for a net loss of 254 lbs K per acre on nutrient-poor sites. Nutrient capital data for K in Wisconsin soils is not readily available, but figures have been reported for similar soils in adjacent states. The K capital of an average Minnesota soil, to a depth of 40 inches, is around 908 lbs/acre (Grigal 2004). Measurements of K capital for 24 Michigan sites showed values ranging from 106 to 1247 lbs/acre, with averages of 120 lbs/acre for a group of outwash sands, 338 lbs/acre for outwash sands with loamy inclusions, and 810 lbs/acre for loamy glacial till soils (Padley 1989).

This analysis indicates that if red pine foliage and branches are removed from the sandiest sites at thinnings and final harvest, K could be depleted before the end of the first rotation. On outwash sands with loamy inclusions, which are typical red pine sites, K depletion could occur during the second rotation. These calculations are estimates based on limited data but indicate that caution is warranted in nutrient management of red pine sites.

Table 32.4. Biomass of red pine plantation thinnings and final harvest, and estimated potassium (K) in harvested trees. Plantation yield data are from Bassett (1984), biomass equations are from Ter-Mikaelian and Korzukhin (1997), and K concentration data are from Perala and Alban (1982).

Age at thinning and final harvest	Biomass of harvested trees: bole + bark	Biomass of harvested trees: branches + foliage	K in bole + bark of harvested trees (5% green tree retention at final harvest)	K in branches + foliage of harvested trees (5% green tree retention at final harvest)	80% of K in branches + foliage of harvested trees (5% green tree retention at final harvest)
	tons/acre		*lbs/acre*		
30	15.3	4.6	15.5	20.1	16.0
40	14.9	4.9	14.9	22.5	18.0
50	6.0	2.1	5.9	10.2	8.2
60	13.4	5.1	13.2	25.3	20.2
70	12.5	4.9	12.2	25.3	20.3
90	11.4	4.8	11.1	26.2	21.0
120	71.6	32.0	65.7	173.9	139.2
Totals	**145.0**	**58.5**	**138.5**	**303.6**	**242.9**

3.2.2 Site Quality

3.2.2.1 Range of Habitat Types

See Chapter 12 – Forest Habitat Type Classification System for information summarizing the system and the habitat type groups.

The red pine cover type occupies about 4% of statewide forest land acres (1996 FIA). It currently is more common in northern than in southern Wisconsin (Figure 32.5 and Figure 32.6). Within the state, about 65% of red pine cover type acres and 73% of red pine net growing stock volume occur on northern habitat types. Southern Wisconsin habitat types contain about 35% of statewide red pine acres and 27% of the volume.

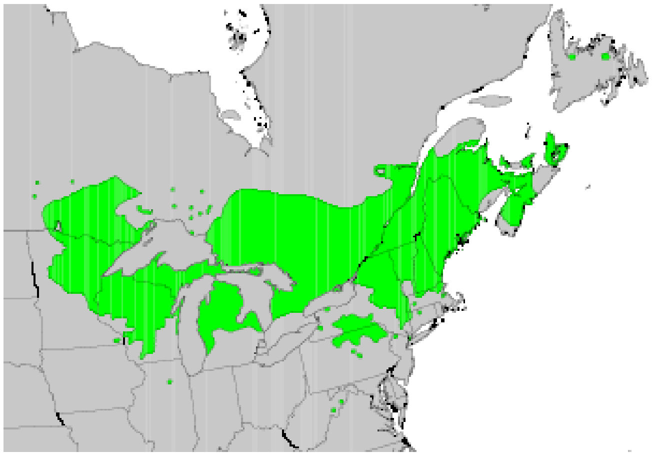


Figure 32.5. Range map for red pine.

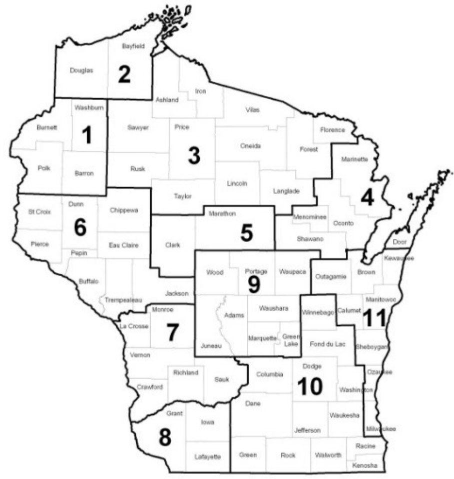


Figure 32.6. Forest habitat type regions. Regions 1-5 generally represent northern and 6-11 southern Wisconsin.

Northern Wisconsin Habitat Types

In northern Wisconsin, the occurrence and relative growth potential of the red pine cover type varies by habitat type groups and habitat types (Table 32.5 and Figure 32.7Figure 32.7). Red pine is a common cover type on very dry to dry and dry to dry-mesic sites (habitat type groups); about 70% of the red pine cover type acres and 64% of the red pine volume in northern Wisconsin occur on these two groups. Red pine is a minor cover type on the dry-mesic, mesic, and mesic to wet-mesic habitat type groups. It generally does not occur on wet-mesic to wet sites.

Southern Wisconsin Habitat Types

In southern Wisconsin, the occurrence and relative growth potential of the red pine cover type varies by habitat type groups and habitat types (Table 32.6 and Figure 32.8). Red pine is a common cover type on dry sites; this habitat type group contains about 73% of the red pine cover type acres and 63% of the red pine volume in southern Wisconsin. Red pine plantations occur, but are uncommon, on most other habitat type groups in southern Wisconsin.

Red pine reaches its native range limit in southern Wisconsin (Figure 32.1 and Figure 32.5). The only southern habitat type region entirely within the native range of red pine is region 9 (Figure 32.6); in this region, the dry and dry-mesic habitat type groups are predominant. Habitat type regions 6, 7 and 8 in the western Driftless region, occur at the historic western and southern limits of the natural range of red pine. Habitat type regions 10 and 11, in southeastern Wisconsin, are mostly out of range.

Plantations have been established in southern Wisconsin, outside of or near the natural range limits for red pine, on dry-mesic to mesic, nutrient rich, loamy soils. Long-term growth, productivity, and tree health are uncertain. Observations of plantation performance typically indicate excellent early growth. However, at comparatively young ages, anywhere between 20 and 60 years old, tree health and mortality problems often develop and stand growth slows or stagnates.

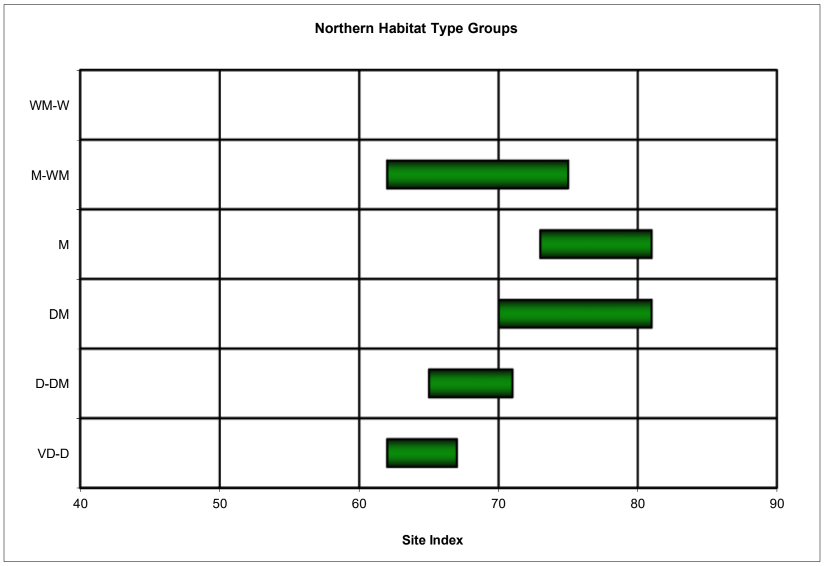


Figure 32.7. Site index for red pine by northern habitat type groups (from 1996 FIA). Bars indicate the 95% confidence limits for the mean. FIA data was insufficient to develop site index values for all habitat type groups.

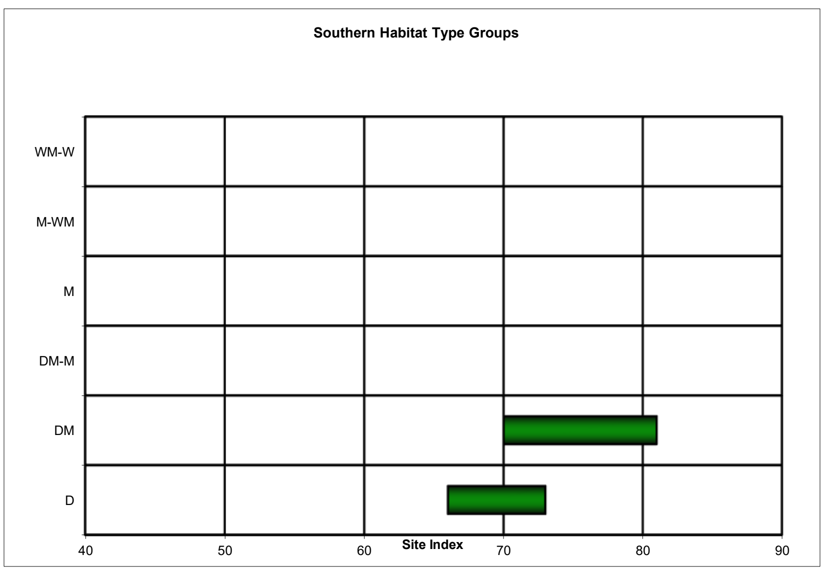


Figure 32.8. Site index for red pine by southern habitat type groups (from 1996 FIA). Bars indicate the 95% confidence limits for the mean. FIA data was insufficient to develop site index values for all habitat type groups.

Table 32.5. Red pine cover type – estimated relative growth potential by northern habitat type group and habitat type.

Northern Habitat Type Groups	Estimated Relative Growth Potential for Red Pine Cover Type[1]				
	Fair	Good	Good to Excellent	Excellent	Excellent[2]
Very Dry to Dry	PQE PQG PQGCe	PArV PArV-U PArVAo QAp			
Dry to Dry-mesic			PArVHa PArVAm PArVAa PArVAa-Vb PArVAa-Po PArVPo		
Dry-mesic				AVVb AVDe AVCl AVb-V AVb	TFAa ACl AAt ATFPo
Mesic					AFVb ATM ATFD ATFSt AAs ATD ATDH AHVb AFAd AFAl ACaCi AOCa AH
Mesic to Wet-mesic, and nutrient poor		PArVRh ArVRp ArAbVCo ArAbVC			
Mesic to Wet-mesic, and nutrient medium to rich	The red pine cover type generally does not naturally occur on these sites. Once established, growth potentials are generally good. Habitat types: ArAbSn, ArAbCo, TMC, ASnMi, AAtRp, ATAtOn, ASaI, ACaI, AHI				
Wet-mesic to Wet	Red pine will not survive and grow in most lowlands, and does not naturally occur. All sites – no habitat types – nutrient poor organics, to mineral swamps, to rich alluvial bottomlands.				

1 – Estimation of relative growth potential for red pine cover type based on:
red pine cover type average volume/acre, red pine site index, and potential tree vigor and form.
2 – Excellent growth potential once established, however the cover type generally does not naturally occur on these sites.

Table 32.6. Red pine cover type – estimated relative growth potential by southern habitat type group and habitat type.

Southern Habitat Type Groups	Estimated Relative Growth Potential for Red Pine Cover Type[1]		
	Good	Excellent	Excellent[2]
Dry	PEu PVGy PVCr PVG PVHa		
Dry-mesic		ArDe-V ArDe ArCi ArCi-Ph AArVb AQVb-Gr	AArL
Dry-mesic to Mesic			AFrDe AFrDeO ATiFrCi ATiFrVb ATiDe ATiDe-Ha ATiDe-As
Dry-mesic to Mesic (phase)			AFrDe(Vb) ATiFrVb(Cr) ATiCr(O) ATiCr(As) ATiDe(Pr)
Mesic (phase)			ATiFrCa(O) ATiAs(De)
Mesic			ATiSa-De ATiSa ATTr AFTD AFH ATiFrCa ATiCa-La ATiCa-Al ATiCa ATiH AFAs-O AFAs
Mesic to Wet-mesic	PVRh		
Mesic to Wet-mesic	No habitat types defined. The red pine type generally does not naturally occur on these sites. Once established, growth potentials are generally good.		
Wet-mesic to Wet	Red pine will not survive and grow in most lowlands, and does not naturally occur. All sites – no habitat types – nutrient poor organics, to mineral swamps, to rich alluvial bottomlands		

1 – Estimation of relative growth potential for red pine cover type based on:
red pine cover type average volume/acre, red pine site index, and potential tree vigor and form.
2 – Excellent early growth potential once established, however the cover type generally does not naturally occur on these sites. Many of these sites occur outside of or near the natural range limits of red pine. Long-term growth, productivity, and tree health are uncertain.

3.2.5 Wildlife

Red pine provides habitat and shelter for wildlife. Young stands are used primarily for shelter. Older stands with closed canopies provide thermal cover. Seeds of red pine can be an important food source for some mammals and birds. Because red pine is a long-lived tree it can serve as a legacy during either natural or artificial stand regeneration. Individual trees or small groups can be important to many wildlife species as nesting platforms or as cavity producers.

Red pine generally grows with associates in natural stands. Wildlife species will benefit from management practices that attempt to simulate natural conditions. Management of natural stands of red pine should recognize the contribution to wildlife of the associated species while maintaining vigor and health of the red pine in the stand.

Plantation management of red pine has often been conducted on open sites and the resulting stands have been relatively simple. Encouraging the development of structural complexity in red pine plantations will benefit wildlife. The presence of ground and shrub layer vegetation in red pine stands in central Wisconsin increased the use of this habitat type by deer, ruffed grouse, and songbirds. Both vertical and horizontal structure can be increased during planting and subsequent treatments. Variable density thinnings with gap establishment will encourage recruitment of multiple layers of vegetation within the plantation. Retention of individuals or small clumps of mature red pine at the time of stand regeneration will increase the value of the plantation to wildlife species; however, disease problems (i.e. *Sirococcus* and *Diplodia*) can occur when red pine seedlings are establishing under mature red pine.

Tree species diversity within red pine plantations is desirable for wildlife. This species diversity can be planned during plantation establishment or encouraged during subsequent thinnings. A mix of species including hardwoods can be planted at the time of stand establishment. In many cases, other species of trees or shrubs can be allowed to remain after establishment of a new stand. Regardless of the source, favoring mast producing shrubs and trees will have the highest value to wildlife dependent on this food source.

<u>Recommendations:</u>

- Increase compositional (species) diversity within stands
    - When establishing plantations include a component of other species either directly or through allowing tree species already present to remain.
        - New plantations should have some areas of different vegetation, either openings allowed to regenerate naturally or intentionally planted clumps of different appropriate species.
        - Large plantations should maximize the amount of interface between the plantation and other vegetation types.

    - During intermediate treatments, maintain species diversity. In homogeneous plantations, consider creating some gaps or patches to recruit natural regeneration of other species. Variable density thinning can facilitate the variable recruitment of understory species.

- Increase structural diversity within stands
    - Develop and maintain large trees, cavity trees, snags, and coarse woody debris
        - Retain both living and dead legacies during stand rotations.
        - Retain wildlife trees during intermediate treatments.

    - Employ variable density thinning to establish structural complexity within planted stands.

- Manage some stands on extended rotations to develop both stand and landscape compositional and structural diversity.
- Develop and successfully apply methods to naturally regenerate red pine, either in natural stands or in plantations nearing rotation age.

3.2.6 Endangered, Threatened and Special Concern (ETS) Species

Several uncommon species are associated with pine and mixed pine forests (e.g. see northern dry-mesic forest community in the Wisconsin Wildlife Action Plan (https://dnr.wi.gov/topic/wildlifehabitat/actionplan.html). Maintaining a conifer component in the landscape is important for biodiversity. However, pine plantations are ecologically deficient in numerous ways compared to native forest communities.

The most important rare species-related consideration for this type is whether or not to establish or re-establish a plantation on a given site. Planting pine will reduce or eliminate habitat, at least temporarily, for the vast majority of the species comprising Wisconsin's biological diversity, as few species utilize plantation habitats compared to other forest types. Therefore, consideration should be given to biological hotspots, rare community types such as prairie/barrens remnants, and other ecologically important areas when locating and designing plantations. In general, barrens and prairie communities should be avoided whenever possible when establishing plantations, as there are numerous rare species associated with these types (see "Landscape Considerations" for more information regarding plantation siting). Where plantations already exist, there are some techniques can increase community diversity and improve habitat for certain species.

In both natural and planted stands, various stand and landscape-level considerations are important for maintaining habitat for rare species. The "Landscape Considerations" and the "Wildlife Management Considerations" sections outline numerous opportunities to enhance forest diversity and improve species habitat; these include retaining structural legacies, improving forest structural and species diversity, using fire as a management tool, managing for patches of older forest, and considering the stand in the broader landscape context. In addition, rare species can sometimes be accommodated by protecting special habitats such as cliffs, rockslides, prairie/savanna openings, and vernal features.

Considering a broad suite of ecological factors for a site, including its relationship to the surrounding landscape, can enrich the overall forest for many species and improve their chances for survival. In certain cases, however, managers may need to consider accommodating a single rare species known from an area. For example, certain rare plants associated with barrens and prairie habitats may be found in areas where plantations have already been established. By providing adequate sunlight and avoiding herbicide or other treatments that might eliminate these plants, these species can be accommodated, at least for the short term. The table at the end of this section provides some examples, but other sources should be referenced. Usually modifications designed to accommodate a species can be designed to achieve multiple benefits.

Rare animals occupying red pine forest are mostly found in young (1 to 10 years) and older (> 50 years) forests. Pine-dominated forests in the oldest age classes are currently lacking across most of the state. Rare plants associated with red pine are generally found in stands of natural origin with certain characteristics. Special consideration related to the amount of shade, soil disturbance, and use of herbicides may be needed to maintain habitat for these plants.

<u>Structural Retention at the Time of Regeneration Harvest</u>
Retaining structural features from the original red pine stand, such as large vigorous trees, cavity trees, snags, and coarse woody debris can enhance structural complexity. Structural retention is modeled on the biological legacies that remained after natural forest disturbances. Even under the most intense historical fires many individual trees and groves survived. Consider retaining reserve trees and snags in even aged prescriptions to provide habitat.

Little quantifiable data exists on how much structure to retain. Developing standard prescriptions would require thorough analyses of species-specific requirements and response to various treatments. In general, retention of old trees can provide benefits such as distinctive architecture with large branches that are used as movement corridors or the foundation for large nests, cavities (both present and future), diverse habitats for insects and spiders which provide the prey base for vertebrates, and maintenance of diverse fine root and fungi systems in the soil.

<u>Identify Special Habitats</u>
Many rare species are limited in their distribution to microhabitats within larger blocks of forest. Habitats such as cliffs, vernal or ephemeral pools, seeps or springs, rock outcrops, or prairie/savanna remnants may harbor rare species. As only a portion of Wisconsin's rare species populations have been documented to date, management of these habitats is important to allow undocumented species to persist or for future species to colonize these areas. Often special habitats can be protected while achieving other silvicultural goals such as the retention of biological legacies (see Chapter 24 for more information).

Cliffs may require one of two different approaches, depending on their physical characteristics and the species present. For moist cliffs, sometimes exhibiting seepage flow, modify harvests near the feature to maintain shading and moisture for species requiring those characteristics. For dry cliffs with species requiring more open conditions the removal of shade, especially by removing trees from the base of the cliff, may greatly improve microhabitats.

Vernal features such as ephemeral ponds are uncommon on the sandy sites where natural red pine stands are typically found. Shade should be retained on pools found within forests, – e.g., see the Northern Hardwoods chapter for a discussion. In many cases, pine plantations have been established on former prairie/barrens sites that were regularly affected by fire such as those found in the Northwest Sands. In these areas, there may be benefits to greatly reducing shade around vernal pools, as they may contain species adapted to more open conditions.

Biological hotspots such as bird rookeries, bat hibernacula, herptile hibernacula, and migratory bird concentration areas can harbor many rare species. These hotspots can be permanent as with hibernacula, or ephemeral in the case of rookeries. Different strategies may apply, depending on the situation. In any situation when these hotspots are encountered, consultation and advice from wildlife or endangered resources specialists should be sought.

Historically, natural and anthropogenic fires occurred across Wisconsin's landscapes for at least a few thousand years. Fire disturbance of low to moderate intensity and frequency was key to maintaining the northern dry-mesic forest type in the past. Prescribed Fire may reduce competition from broadleaf trees and shrubs while improving habitat for other plant species associated with these forests. These species populations can be greatly enhanced by use of fire, often in combination with understory removal.

Adaptive management is important, because many aspects of endangered and threatened species management are not precisely known, and managers need to rely on the best available information for species life history or ecological disturbance patterns. Information on rare species' responses to silvicultural techniques in working forests is notably lacking. Documenting the different approaches used by foresters across the state can benefit other managers and biologists and to help to better inform conservation efforts in the future.

Table 32.7. Select rare species that can be associated with red pine stands, their general habitat preferences, and sample management considerations for which they may benefit. These are meant as broad considerations for planning purposes, rather than avoidance measures; please consult additional sources for life history information. The species list is not meant to be exhaustive.

Rare Species	Habitat	Mgmt Considerations
Plant Species		
Large Round-leaved Orchid- *Platanthera orbiculata - SC*	Acid soils areas with little competition such as heavy pine duff. Most often seen in older pine forests.	Extended rotation or old-growth management.
Hooker's Orchid – *Platanthera hookerii -SC*	Acid soils areas with little competition such as heavy pine duff. Most often seen in older pine forests.	Extended rotation or old-growth management
Dwarf Milkweed – *Ascelpias ovalifolia - T*	A barrens species occasionally also found in older native red pine forest in Jackson County. Sometimes uses brushy openings, roadsides, and rights-of-way.	No landings on populations. Provide open patches for sunlight.
Crinkled Hairgrass (*Deschampsia flexuosa*)	Pine forests and barrens, mostly near the Great Lakes	Provide open patches or manage near minimum stocking levels.
Giant Rattlesnake Plantain – *Goodyera oblongifolia – SC*	Scattered locations under Apostle Islands red pines.	Park rules guide management where it has been found.

Rare Species	Habitat	Mgmt Considerations
Purple Clematis - *Clematis occidentalis* - SC	Cool forests (usually mixed conifer-hardwoods), often on cliffs and ravines with igneous rock (basalt, quartzite).	Seems to occur in less dense areas within known habitat; open patches may be beneficial.
Giant Pinedrops - *Pterospora andromedea* – E	Known only from white pine stands in WI, but has been found in dry forests with other conifers in MI.	Extended rotation or old-growth management
Animal Species		
Northern Prairie Skink - *Eumeces septentrionalis – SC*	Barrens in Northwest Sands. Will inhabit 1 to 10 year old red pine plantations.	Maintain diverse ground layer composition.
Bullsnake – *Pituophis catenifer – SC*	Barrens in Northwest Sands, Central Sand Plains and Western Coulee and Ridges. Will inhabit 1 to 10 year old red pine plantations.	Maintain diverse ground layer composition.
Sharp-tailed Grouse – *Tympanuchus phasianellus – SC*	Barrens in Northwest Sands. Will inhabit 1 to 10 year old red pine plantations.	Maintain diverse ground layer composition.
Northern Goshawk – *Accipiter gentilis – SC*	Occasionally nest in old red pines	Follow forest raptor protocols.
Bald Eagle – *Haliaeetus leucocephalus – SC*	Occasionally nest in old red pines	Follow Bald Eagle management guidelines
Whip-poor-will – *ECaprimulgas vociferous - SC*	Mature pine and oak woods.	Extended rotation and landscape planning
Insect Species		
Rocky Mountain Sprinkled Grasshopper – *Chloealtis abdominalis - SC*	Dry pine forests and barrens. Will inhabit 1 to 10 year old red pine plantations.	Maintain diverse ground layer composition.
Huckleberry Spur-throat Grasshopper – *Melanoplus fasciatus - SC*	Dry pine forests and barrens. Will inhabit 1 to 10 year old red pine plantations.	Maintain diverse ground layer composition.

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 landowner stand management objectives should be detailed. In-depth and accurate stand assessment will facilitate discussion of stand management options and objectives within the context of realistic and sustainable property management goals.

Red pine stand assessment should include quantifying variables such as:

- Present species composition

  - Canopy, shrub, and ground layers
  - Sources of regeneration
  - Potential growth and competition

- Stand structure
  - Size class distribution and density
  - Age class distribution

- Stand and tree quality
- Site quality - The habitat type is the preferred indicator of site potential. Other indicators of site potential include site index, soil characteristics, and topographical characteristics. Site has a strong influence on volume growth and potential yield.
- Stand and site variability

4.2 Key to Recommendations

Note: The following recommendations assume the management objective is to maximize tree vigor and stand growth to optimize productivity (quantity and quality) of a variety of timber products.

Table 32.8. Management options based on stand conditions.

A. Seedling/Sapling Stands (<5" DBH)

1. Fully stocked stands (400-1000 TPA) or overstocked stands	Maintain 400 to 1000 TPA that are vigorous and free-to-grow. When needed, release operations are recommended to control competition and maintain tree vigor.
1. Understocked stands (<400 TPA)	Interplanting will be necessary and should be implemented within the first two years of initial planting. Control competing vegetation, and interplant red or white pine seedlings. If beyond two years in the ground, then site prep and replant.

B. Poletimber and Sawtimber Stands (≥5" DBH)

1. Fully stocked stands or overstocked stands	**2**
1. Understocked stands	**5**
2. Poletimber – first thinning	**3**
1. Poletimber – previously thinned, or Sawtimber	**4**
3. Distinct rows	Review thinning guidelines. Determine if a thinning could be recommended. If a thinning will not be recommended, then determine a date for future reassessment of growth and thinning opportunity.

	If a thinning will be prescribed, then determine target residual basal area. Follow guidelines for "**Mechanical Row Thinning** or **Mechanical Row and Low Thinning**"
3. Indistinct rows or natural stands	Review thinning guidelines. Determine if a thinning could be recommended. If a thinning will not be recommended, then determine a date for future reassessment of growth and thinning opportunity. If a thinning will be prescribed, then determine target residual basal area. Follow guidelines for "**Mechanical Strip and Low Thinning**"
4. Poletimber – previously thinned	Review thinning guidelines. Determine if a thinning could be recommended. If a thinning will not be recommended, then determine a date for future reassessment of growth and thinning opportunity. If a thinning will be prescribed, then determine target residual basal area. Apply **crop tree selection** and **standard order of removal** criteria.
4. Sawtimber	Review thinning guidelines. Determine if a thinning could be recommended. If a thinning will not be recommended, then determine a date for future reassessment of growth and thinning opportunity. If a thinning will be prescribed, then determine target residual basal area. Apply **crop tree selection** and **standard order of removal** criteria. If first thinning, consider adaptations for equipment access. Harvest at rotation age.
5. Landowner objectives include red pine management, and the site is suitable for red pine management.	Cut overstory, prepare site, and replant to red pine. When harvesting and replanting red pine, consider waiting two years before replanting to reduce risk of seedling damage from insect infestations
5. Landowner objectives indicate a preference for other feasible cover types, or the site is not suitable for red pine management.	Convert to another cover type; apply artificial or natural regeneration methods. If planting to other pine, consider waiting two years before replanting to reduce risk of seedling damage from insect infestations

5 SILVICULTURAL SYSTEMS

A silvicultural system is a planned program of vegetation treatment during the entire life of a stand. All silvicultural systems include three basic components: intermediate treatments (tending), harvesting, and regeneration. For red pine stand management, even-age management is recommended.

- Periodic thinnings based on basal area control are recommended.
- Artificial regeneration is the most reliable and most commonly practiced method to regenerate stands. Proper site selection, site preparation, and competition control are important for artificial regeneration to be successful.

5.1 Seedling / Sapling Stands

Efficient and successful stand establishment, and maintenance of early growth and productivity have a disproportionate effect (as compared to later intermediate treatments) on timber productivity over the rotation.

Stocking should be maintained between 400 and 1000 well distributed trees per acre. Sapling crop trees may be most productive with ≥50 ft^2 of growing space.

If mortality becomes excessive and minimum stocking levels are not maintained, then reinforcement planting will be necessary and should be implemented within the first two years of initial planting. Control competing vegetation, and interplant red or white pine seedlings. If beyond two years in the ground, then site prep and replant.

Once established, red pine seedlings and saplings generally exhibit optimal vigor (growth and health) when exposed to (near) full sunlight. Crop trees that are maintained in free-to-grow conditions have the greatest potential to maximize growth and productivity. When needed (before seedlings become overtopped), release operations are recommended to control competition and maintain tree vigor.

- Cleaning (sometimes termed precommercial thinning) overstocked stands will maintain crown development and diameter growth rates.
- Liberation can reduce shade cast by older, overtopping trees; however, retaining reserve trees of other species is recommended (see Chapter 24).
- Weeding can control undesirable vegetation (e.g. exotic species or competing shrubs and herbs)

5.2 Intermediate Treatments

5.2.2 Thinning

<u>Basic Concepts</u>
Intermediate treatments generally are designed to enhance tree growth, health, and quality, and stand composition, structure, and value. Thinning is a cultural treatment conducted in stands past the sapling stage to reduce stand density. It entails the removal of trees to temporarily reduce stocking to concentrate growth on the more desirable trees. Thinning can impact stand growth, compositional and structural development, and economic yield. It

provides the main method, implemented between regeneration and final harvest, to increase the economic productivity of stands. Normal thinning does not significantly alter the gross production of wood volume.

Objectives of thinning include any of the following:

- Enhance the vigorous growth of selected trees through the removal of competitors. Larger diameter, more valuable trees can be grown in a shorter period of time.
- Enhance tree health. Thinning maintains tree vigor and strength and anticipates losses.
- Harvest most merchantable material produced by the stand during the rotation. Trees that would die from competition are harvested and utilized for timber products.

Application of thinnings can increase economic yields:

- Harvest anticipated losses of merchantable volume.
- Yield of income and control of growing stock during rotation.
- Increased value from rapidly growing larger diameter trees.
- Increased value from improvements in product quality.

A schedule of thinning for a stand should identify the thinning methods to be used, the intensity of application, and when thinnings will occur. Thinning schedules should be systematically and carefully developed because the effects of these cultural practices will be manifested in future growth and development and will influence future management options.

Stocking charts (Figure 32.10Figure 32.9) generally guide density management during intermediate thinning treatments. In managed red pine stands, maintain stocking between the A-line and B-line on the stocking chart. Do not allow stand density to surpass the A-line, and do not reduce stand density to below the B-line. Within this range (between A- and B-lines), trees fully utilize (occupy) the site, and stand growth and merchantable board-foot volume yield are optimized. Thinning can occur at any time and stocking managed at any level as long as stand density is maintained between the A- and B-lines.

Advantages of higher residual thinning densities in red pine stands:

- Increased options for crop tree selection.
- Potential to reduce size and persistence of branches on lower bole.
- Potential to reduce stem taper. Taper is self-correcting over time, as the crown moves upwards and height growth declines.
- Greater flexibility for responding to mortality and pest problems.
- Products – increased yields of smaller diameter products and poles.
- Increased cubic foot volume growth rates of young stands.

Advantages of lower residual thinning densities in red pine stands:

- Increased crown vigor and tree diameter growth rates.
- Concentrates growth on best quality trees.
- Products – increased sawtimber production at younger ages.
- Better development of shrub and herb layers and increased within stand compositional and structural diversity.

The effects of thinnings are temporary. After each thinning, the remaining trees grow taller, diameters increase, crowns expand, and canopy gaps close; stand density increases. Periodic thinnings can maintain crown vigor and accelerated diameter growth rates of crop trees. Factors to consider in determining when to conduct further thinning operations include: stocking, diameter distribution and growth rates, crown development and vigor, timber yields and economics, landowner goals and stand management objectives.

<u>Thinnings – Timing and Intensity</u>
Refer to stocking chart (Figure 32.10). Maintain stocking between the A-line and B-line. Thinning can occur at any time as long as stand density is maintained between the A- and B-lines. The A-line is not a thinning "trigger." When to thin depends on management objectives, stand conditions, and operability.

Typically, thinning is implemented when basal area stocking is at or above the midpoint between the A- and B-lines, but before stand density reaches the A-line. Reduce stocking to a density near the B-line, choosing a residual basal area that will accommodate landowner objectives. A general rule of thumb is do not remove >50% of the basal area in any one thinning operation.

Overstocked stands (greater than A-line stocking), where thinnings have been delayed, may be comprised of tall, thin, small-crowned trees that are susceptible to wind, snow, and ice damage following heavy thinning. In these stands, to develop tree vigor and strength, thin lightly and frequently, with increasing intensity, for the first several thinnings, until target residual densities are achieved. A general rule of thumb is do not remove >33% of the basal area during the initial thinning.

Standardized thinning regimes (simplified, general guidelines) aim to sustain consistent growth and productivity throughout the rotation, and to produce a variety of timber products from thinnings and final rotational harvest.

- Poletimber (5-9 inches dbh)
  - Typically operable when basal area is 100-180 sq. ft. per acre
  - As a general guide, reduce basal area to slightly above the B-line, to 70-110 sq. ft. per acre; 90 sq. ft. per acre can provide a standard target residual basal area.

- Small sawtimber (10-15 inches dbh)
  - Typically operable when basal area is 140-200 sq. ft. per acre
  - As a general guide, reduce basal area to slightly above the B-line, to 100-140 sq. ft. per acre; 120 sq. ft. per acre can provide a standard target residual basal area.

- Large sawtimber (>15 inches dbh)
  - Typically operable when basal area is 160-220 sq. ft. per acre
  - As a general guide, reduce basal area to slightly above the B-line, to 110-160 sq. ft. per acre; 140 sq. ft. per acre can provide a standard target residual basal area.

Thinnings are usually implemented every 8-12 years in young pole-sized stands and every 10-20 years in older sawtimber stands.

An important consideration when thinning red pine stands is the identification and control of Annosum root rot and red pine pocket mortality. For Annosum root rot, prevention is key. A new infection site primarily originates when spores land on freshly cut stumps; the fungus also spreads through root contact and root grafting. If Annosum is not present in the stand, consider treating freshly cut stumps with a fungicide (e.g. “Sporax,” “Cellu-Treat”) to prevent new infections. If Annosum is present in the stand, follow detailed Forest Health Protection guidelines.

Red pine pocket mortality is apparently caused by a complex of insects and the fungi *Leptographium*. Pockets typically start small with one to a few dead trees surrounded by trees that have reduced shoot growth and thin crowns. Each year, a few trees on the pocket edge may die and the edge of the pocket expands. *Leptographium* spp. move below ground through root contact and the pocket expands about 1 chain every 10 – 15 years. Cut dead trees and trees that are showing dieback and/or yellowing of the foliage within and adjacent to the pocket; consider cutting a buffer area of healthy trees around the pocket. As long as total pocket area is not excessive, pockets can be treated as natural openings to provide habitat diversity. See the following section, Forest Tree Health Management Guidelines for Red Pine, for additional information and references.

<u>First Thinning – Methods</u>
At least 400 trees per acre are required to provide minimum recommended stocking when stands reach poletimber size (B-line stocking when average dbh of trees in stand is 5 inches). Most red pine stands reach the poletimber size class in 15-30 years following planting; the first thinning generally occurs at the age of 20-25 years, when the trees are poletimber sized and merchantable products can be harvested.

- Plantations with distinct rows
    - Mechanical row thinning
        - Mechanical row thinning is an efficient method for the first thinning. Every other row or every third row is mechanically removed. The space created within the cut rows should be wide enough to accommodate processors and forwarders. Maintain stocking between the A-line and B-line, as recommended in the preceding discussion of thinning intensity.

    - Mechanical row and low thinning
        - Mechanical row and low thinning methods can be integrated for the first thinning. Every fifth row is mechanically removed, and a low thinning is applied within the remaining rows. The space created within the cut rows should be wide enough to accommodate processors and forwarders. Maintain stocking between the A-line and B-line, as recommended in the preceding discussion of thinning intensity.

- In very dense plantations where removal of individual rows will not provide access strips of sufficient width to accommodate equipment (processors and forwarders), then alternatives are:
    - Mechanical row thinning, removing two adjacent rows and retaining two adjacent rows.
    - Mechanical row thinning and low thinning, removing two adjacent rows and retaining five rows. To achieve target residual basal area stocking, a low thinning is conducted within the retained rows.

Maintain stocking between the A-line and B-line, as recommended in the preceding discussion of thinning intensity.

On steep topography with equipment limitations, where rows were planted on the contour, follow guidelines for “Plantations with Indistinct Rows,” running the access strips up and down the slope.

Plantations with Indistinct Rows and Natural Stands – Mechanical Strip and Low Thinning
In plantations where rows are indistinct and in natural stands, mechanical strip thinning combined with low thinning is recommended. Access strips of sufficient width for mechanized access are systematically designated and cut throughout the stand. Depending on equipment needs and expectations, cut access strips generally are 10-15 feet wide. Typical spacing of cut access strips is every 50-60 feet. To achieve target residual basal area stocking, a low thinning is usually conducted within the leave strips. Maintain stocking between the A-line and B-line, as recommended in the preceding discussion of thinning intensity.

Subsequent Thinnings - Methods
Free thinnings that integrate low and crown thinning techniques are recommended (see Chapters 23 and 24).

Select crop trees for retention based on retention criteria:
- Low risk of mortality or failure (main stem breakage)
- Good crown vigor
    - Dominant or codominant trees
    - Good silhouette and healthy needles
    - Good crown/length ratio – live crown ratio >30% will provide best response to thinning

- Good stem quality
- Desirable species

Trees may also be selected for retention to achieve other objectives, such as aesthetics or wildlife management.

Select trees to cut, following the standard order of removal:
- High risk of mortality or failure (unless retained as a wildlife tree)
- Release crop trees

- Low (lower) crown vigor
- Poor (poorer) stem form and qualit
- Less desirable species
- Improve spacing

Alternatively, thinnings can be either low thinnings or crown thinnings, depending on assessment of tree and stand growth and mortality. Low thinnings are most applicable in early thinnings, particularly poletimber stands. Low thinnings mostly remove slower growing and higher risk trees (suppressed, intermediate, and poor codominants); heavy low thinning is recommended in order to provide some release to the crowns of crop trees. Crown thinnings mostly remove lower vigor, poorer quality canopy trees in order to favor (release crowns of) the best trees in the dominant and codominant crown classes.

5.2.3 Prescribed Fire

Prescribed surface fire in mature red pine stands can be an effective management tool for eliminating shrub competition, reducing thick duff layers, and preparing mineral seedbeds. Young stands of red pine 1-49 years, are susceptible to damage and mortality, however, once the tree reaches 60 feet tall (roughly 50 yrs old), the bark is thick enough to protect the cambium and crown from extreme fire damage (Rouse 1988). Burning is a less expensive alternative to other site preparation techniques, however, due to the risk and related liability issues it may not always be the best method. Depending on the type and intensity of the burn, some very intense burns may cause some damage to the tree and affect its merchantability. Burning, soon after timber harvest with available slash fuel, can be an effective tool to reduce competition from undesirable trees and shrubs. Growing season fires, conducted repeatedly over several (2-4 years) growing seasons, have been effective at controlling dense shrub (hazel) competition and exposing mineral soil (Buckman 1964). The reduction in hazel abundance in stands receiving several growing season burns can last many decades. Burning can also be an effective at exposing the mineral soil and nutrient availability for an adequate seedbed. Slow-burning, cool fires can reduce slash and needle duff, expose soil providing better seedbed conditions for germination.

5.2.4 Pruning

Pruning is a silvicultural practice that can be applied to improve log quality and value; it is implemented to promote the growth of clear, knot free wood on the first log. It is a relatively labor intensive and costly practice, implemented in young stands, and economic returns are not realized until (near) the end of the rotation. The financial efficacy of pruning is questionable.

Knots are created by branches and can degrade log quality. Factors related to log quality and branching include the number of branches, the size of branches, and the persistence of dead branches. In red pine, the size and persistence of branches is somewhat influenced by stand density.

In dense stands, red pine self-prunes comparatively well. In open stands, trees retain lower branches longer, branches grow larger in diameter, and dead branches persist longer. Pruning can be applied to improve log quality, particularly in stands that are managed at lower density to accelerate diameter growth rates. Combining pruning and aggressive thinning can facilitate the production of increased value in a shorter period of time.

If pruning red pine trees, prune only 50-150 potential crop trees per acre, and only on good to excellent sites. Generally, trees are pruned to 17 feet (the first log) in 2-3 pruning operations. Often, the first pruning is to 9 feet when trees are 18-20 feet tall. Always maintain a crown/stem ratio of at least 50% (at least 50% of total height occupied by crown).

Chapter 23 provides further guidance on pruning.

5.2.5 Planting Density

Chapter 22 provides guidelines for artificial regeneration and includes species specific considerations. Efficient and successful stand establishment is critical to long-term growth and productivity. Sites must be properly prepared before planting to facilitate operations and control competition. When harvesting and replanting red pine, consider waiting two years before replanting to reduce risk of seedling damage from insect infestations. Planting density (spacing) recommendations depend on many factors, including management objectives, silvicultural practices planned, and planting conditions.

Recommended planting densities range from 500-1000 trees per acre (TPA). At least 400 well distributed TPA are required to provide minimum recommended stocking when stands reach poletimber size (≥5 inches dbh); in general, most stands reach the poletimber size class in 15-30 years following planting. Commonly, production-oriented planting densities range from 700-900 TPA.

Advantages of higher planting densities (e.g. 750-1000 TPA):

- Partial mortality less likely to result in understocked conditions.
- Increased options for crop tree selection.
- Potential to reduce size and persistence of branches on lower bole.
- Increased cubic foot volume growth rates of young stands.
- Release – less competition from other species (less weeding)

Advantages of lower planting densities (e.g. 500-750 TPA):

- Lower planting costs.
- Increased tree diameter growth rates.
- Longer retention of abundant shrub and herb layers to enhance plant diversity
- Release – less intra-stem pine competition [less cleaning (precommercial thinning)]

When planting, consider including some species diversity to expand future management options and to provide sustainable forestry benefits. Other species can be included through integrated planting (e.g. white pine), planting patches (e.g. white pine, oak), or natural regeneration in patches (e.g. white pine, oak, birch, aspen) (see following section Managing Mixed Stands).

5.3 Natural Regeneration Methods

Silvicultural methods to regenerate red pine by natural regeneration (seed) are rarely applied. Successful natural regeneration requires a suite of coinciding factors which can be difficult to coordinate. Significant silvicultural considerations that can limit the successful establishment of natural regeneration include seed production, seedbed conditions, moisture availability during the first two growing seasons, sunlight (shade), and competing vegetation.

Shelterwood and seed tree are potential natural regeneration methods for the red pine type. However, they have been poorly studied, and success has been highly irregular. Significant silvicultural considerations include management of overstory seed sources and shade, timing to coordinate site prep and seed production, and competition control. Drought during seedling establishment can be a limiting factor. Rapid brush invasion has been one of the most important causes of failure of red pine reproduction. In addition, disease problems (i.e. *Sirococcus* and *Diplodia*) can occur when red pine seedlings are establishing under mature red pine.

<u>Key Requirements</u>

- Good Seed Crop
    - Very irregular, occurring on average every 3-7 years, with bumper crops every 10-12 years
    - Most seed is dispersed within 40’ during September to November
    - Seed germinates spring to early summer

- Soil Moisture
    - Moist soil throughout spring and summer is essential to germination, survival, and growth. Seedlings are very susceptible to dessication during the first growing season, and somewhat so during the second season.

- Site Preparation
    - Seedbed – bare mineral soil preferred (light pine litter acceptable)
    - Competition control

- Sunlight and Shade
    - >80% crown closure limits establishment
    - Approximately 65% crown closure recommended for initial establishment (shade facilitates moisture retention and may limit competition)
    - <60% crown closure provides best seedling growth and development for establishment (if moisture and competition are not limiting)
    - <20% crown closure provides best growth once established

- Competition Control
    - To ensure seedling survival and vigor

5.3.1 Even-Age Regeneration Methods

Shelterwood/Seed Tree Regeneration Methods

- Seeding cut alternatives
  - Strip Cut (seed tree/shelterwood hybrid)
    - Cut strips 50’ wide and leave uncut strips 15’-20’ wide (removes 70-80% of the overstory)
  - Shelterwood / Seed Tree
    - Recommended cut: 60% crown closure to provide seed and shading
    - Minimum cut: retain up to 70% crown closure
    - Maximum cut: retain 20-30 trees per acre to provide adequate seed coverage with a good seed crop
  - Seed trees retained are desirable species of good vigor and quality
  - Scattered seed trees and strips may be susceptible to windthrow on some sites
- Final overstory removal cut
  - When a well-stocked stand of desirable, vigorous seedlings is well established, ideally in 3-8 years
    - Well-stocked is >500 well distributed seedlings/acre remaining following overstory removal. Stocking requirements prior to overstory removal will depend on overstory density and distribution, and logging methods.
    - Well-established is 2-4 feet tall
  - Remove overstory to ≤15% crown closure to optimize growth of seedlings and saplings.
    - Retention of reserve trees is recommended
    - In general, red pine should not be retained as a reserve tree (over red pine regeneration), because of potential disease incidence (i.e. *Sirococcus* and *Diplodia*)

Recommended Natural Regeneration Process

- Overstory seeding cut, either:
  - Shelterwood cut to 60% crown closure
  - Strip cut
- Wait two or more years for crown development and understory development (sprouts and germinants of competitors)
- Monitor potential red pine seed crops
- Implement site preparation (prepare seedbed and control competition) during late summer before a good or better seed crop
- Monitor regeneration and release as needed to control competing vegetation
- Overstory removal cut
- Release as needed

Overstory Removal
In red pine stands, conditions required to implement overstory removal rarely develop. Overstory removal is an even-aged natural regeneration method implemented in stands at rotation age that removes all trees in one cut to fully release desirable advance regeneration that is well stocked and well established.

- Well stocked is >500 well distributed vigorous seedlings/acre remaining following overstory removal.
- 1000-3000 seedlings/acre prior to logging would facilitate maintenance of adequate stocking following logging damage. Logging damage to regeneration should be minimized to the extent feasible.
- Well established is 2-4 feet tall.

Retention of reserve trees is recommended. In general, red pine should not be retained as a reserve tree (over red pine regeneration), because of potential disease incidence (i.e. *Sirococcus* and *Diplodia*)

Following overstory removal, release may be needed in 1-10 years to maintain seedlings and saplings free-to grow and vigorous.

Reserve Tree Retention
At rotation, when a red pine stand is harvested, retain reserve trees (see Chapter 24).

If red pine will be regenerated, consider disease issues. *Sirococcus* and *Diplodia* can occur when red pine seedlings are establishing under mature red pine. If these diseases are a threat locally, then do not retain red pine reserve trees; do retain reserves of other species if available. Consider creating some species diversity when regenerating the stand to expand future management options.

5.5 Rotation Lengths and Cutting Cycles

Rotation Definition
In even-aged silvicultural systems a 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 (CMAI), target size, attainment of a physical or value growth rate, and biological condition.

Choosing an Appropriate Rotation Age
Selecting when to rotate a stand is based on multiple considerations, including landowner goals, stand condition, and expected future growth. The rotation ages provided are guidelines based on literature, empirical data, 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. Different rotation lengths can result in increased production of some benefits and reduced production of others, and landowner goals will help inform the evaluation of the benefits and costs (ecological, economic, social) associated with different forest management strategies. Below are rotation length guidelines

based on three different management emphases to accommodate a variety of landowner goals.

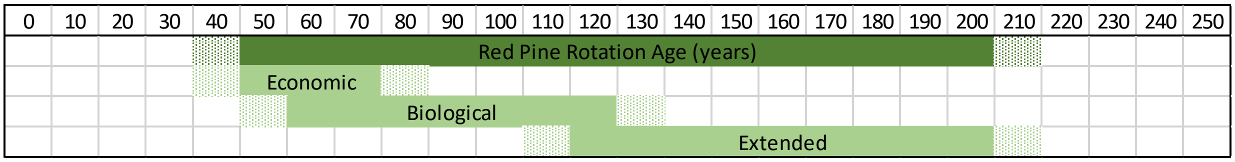


Figure 32.9. Economic, biological, and extended rotation length recommendations for red pine.

5.5.1 Economic Rotation

The economic rotation age seeks to maximize the net present value of the stand. It may only include financial (monetary) aspects but could also include non-timber benefits. The inclusion of non-timber benefits may shorten or lengthen the rotation age depending on the non-timber benefits included. Landowners who choose economic rotation ages generally want to maximize the financial performance of the stand. Economic rotations will vary depending on the target discount rate, frequency of thinnings and other factors including estimated costs and revenues. For more details on the factors that affect economic rotation age, please refer to the Economics Chapter (Chapter 62). Another consideration for plantation red pine in Wisconsin is the optimal diameter and an accurate estimate of time required to achieve it. Generally, once a red pine stand has reached its highest value product class, from a financial perspective net present value is often maximized and it is better to harvest since waiting will not add volume fast enough to compensate for the time value of money. For example, at the time this chapter was published, utility pole markets in Wisconsin were generally the highest value product class for red pines. Research on red pine in the Lake States, as well as actual stands modelled in Wisconsin, indicate that current economic rotations for well managed red pine stands are most commonly maximized between 50-70 years (Grossman and Potter-Witter 1991; Lothner and Bradley 1984; Minnesota DNR 2013; Naurois and Buongiorno 1986; Steigerwaldt 2016). Intensively managed plantations on high quality sites may reach economic rotation prior to 50 years, while unmanaged plantations and/or poor-quality sites may have longer economic rotations. Red pine markets can change and new markets, changing mill standards, or supply chain constraints may affect economic rotation ages.

5.5.2 Biological Rotation

The biological rotation seeks to maximize long-term sustained yield, or volume production. In this guideline, the range in rotation ages is defined at the lower end by the age at which maximization or culmination of mean annual increment (CMAI) growth occurs and at the upper end by the average stand life expectancy. Little objective data exists identifying these endpoints in general and even less by site type. The recommended rotations provided are our best estimates of these endpoints based on the literature and empirical data. The biological rotation range is suitable for a variety of landowner goals. Shorter rotations of 60-90 years tend to maximize cubic foot production, whereas longer rotations of 80-120 years tend to increase board foot production and may accommodate other landowner goals.

5.5.3 Extended Rotation

Extended rotation involves growing stands beyond typical biological rotation ages yet younger than average tree life expectancy, with the objective of managing for both commodity production and the development of some ecological and social benefits associated with older forests. Ecological benefits of extended rotations can include an abundance of large trees, more diverse vertical structure, and greater levels of standing snags and coarse woody debris that support organisms associated with these structures. Most natural origin stands in Wisconsin fall within this age range and are often managed on extended rotation due to their ecological importance and rarity on the landscape.

5.5.4 Flexibility in Rotation Length Guidelines

The recommended rotation ages presented here are appropriate for most stand conditions and landowner goals encountered in plantation and natural origin red pine stands. Foresters may modify these guidelines to accommodate specific stand conditions and management objectives. Modifications to these guidelines should always be scientifically sound. Some of the more common modifications include early rotations due to significant stand health concerns, modifications to regulate a species' age class distribution at the property/landscape level, and accommodations due to operability challenges. In addition, some intensively managed plantations on high quality sites may reach economic rotation and their highest value product class sooner than expected.

5.5.5 Red Pine Plantations Cultivated Outside of the Natural Range

Part of southern Wisconsin is outside of the native geographical range of red pine. On some sites, early growth can be excellent, but stand growth and tree health often decline at relatively young ages. Foresters should monitor tree vigor and mortality; as well as stand growth and productivity on these sites early. As long as vigor and productivity are maintained, continue to manage the stand following standard red pine silvicultural guidelines (i.e., intermediate treatments). If tree vigor declines significantly, stand-level mortality becomes significant, and/or productivity declines (CMAI), then rotate and convert the stand to species more suitable to the site.

5.6 Other Silvicultural Considerations

5.6.1 Managing Mixed Stands

Stands of mixed species composition, but predominantly red pine, can develop through artificial or natural regeneration. Maintaining species diversity within stands provides many potential benefits (compared to managing monocultures), including diverse sustainable forestry benefits (e.g., improved wildlife habitat), increased resilience in response to disturbance (e.g., disease outbreaks), and increased future management options. On sites where red pine most commonly occurs, common associates are white pine, jack pine, oak, aspen, and birch; successional progression tends to be toward white pine and red maple. On richer, more mesic sites, successional progression tends to be toward mesic hardwoods (e.g., maples). Within plantations where red pine is predominant, other species can be included through integrated planting (e.g., white pine), planting patches (e.g., white pine, oak), and natural regeneration in patches (e.g., white pine, oak, birch, aspen).

Mixed pine plantations with red pine predominant will be managed by even-aged systems. Planting design should consider the silvics of each species (e.g., differential growth rates), management objectives, future silvicultural practices (e.g. thinning methods and residual stocking distribution), and planting efficiencies. Species can be planted in single or multiple rows, or in complex mixtures. In most cases, mixed pine stands should be planted at a density of 700-1000 trees per acre and maintained at this stocking level while in the seedling and sapling stages. Seedlings and saplings should be maintained free-to-grow and released as necessary. Poletimber and sawtimber stands are regularly thinned based on basal area control.

Red Pine – White Pine Mixed Stands

See Chapter 31 for guidelines on white pine management. White pine is potentially somewhat longer-lived than red pine. Recommended rotation ages are similar; red pine can be rotated at younger ages, but potential extended rotations are nearly identical. In mixed red-white pine stands, rotation age can be based on either red pine or white pine guidelines; rotation ages ≥100 years are most suited for mixed stands.

In mixed red-white pine stands, both species can be maintained as vigorous associates throughout the rotation. When thinning, consider:

- Methods: In general, free thinnings will be applied; follow guidelines for crop tree selection and order of removal. Row thinning should only be applied at the first thinning if necessary for access and/or if planned for at planting.
- Timing: Thinnings are usually implemented every 8-12 years in young pole-sized stands and every 10-20 years in older sawtimber stands.
- Intensity: Target residual basal areas can be interpreted from the stocking guides; the following thinning guideline should work well: 90-100 ft^2/ac for poletimber, 120-130 ft^2/ac for small sawtimber, and 140-150 ft^2/ac for large sawtimber

Red Pine – Jack Pine Mixed Stands

See Chapter 33 for guidelines on jack pine management. Red pine and jack pine are associates, particularly on dry, nutrient poor sites; however, mixed stands may increase the risk of insect damage to red pine (e.g. root tip weevil and jack pine budworm). Jack pine is generally shorter-lived than red pine, and recommended rotation ages are shorter. In some mixed stands, red pine and jack pine will be managed together throughout a relatively short rotation (e.g. 60-70 years); this scenario is most likely when the harvest of jack pine will leave the remaining red pine stand understocked. In most mixed stands, jack pine will be harvested over several thinnings, and stands will become increasingly dominated by red pine. When thinning mixed red and jack pine stands, follow red pine thinning guidelines; the appropriateness of an initial row thinning will depend on access issues and species spatial distributions.

5.6.2 Red Pine Plantations Cultivated Outside of the Natural Range

Red pine reaches its native geographic range limit in southern Wisconsin (Figure 32.1 and Figure 32.5). Most of southern Wisconsin, as well as the central eastern zone and much of the western coulee region harbored only a few red pine community outliers. Apparently, climate, soils, and/or disturbance regimes did not favor the establishment and maintenance of red pine dominated forests.

Plantations have been established in southern Wisconsin, outside of the natural range limits for red pine. Soils typically are dry-mesic to mesic, nutrient rich, and loamy; some soils are calcareous either near the surface or in the subsoil. Long-term growth, productivity, and tree health are uncertain, but observations indicate that red pine is not well adapted to the environment, and that stands often decline at young ages.

Observations of plantation performance typically indicate excellent early growth. However, at comparatively young ages, anywhere between 20 and 60 years old, tree health and mortality problems often develop and stand growth slows or stagnates. In southwestern Wisconsin, red pine plantations often show signs of stress and decline very early, around 20-30 years old, and often by age 40-50 years growth has stagnated and significant mortality can result in understocked stands. Similar patterns of decline have been observed in southeastern Wisconsin, but signs of tree stress and stand decline generally occur in somewhat older stands. Stressed trees lack vigor, crowns may be small and thin, and the tips of branches may appear tufted (lion’s tail); stressed trees may not respond to thinning. In general, many red pine stands do not remain productive (volume/acre/year) until or beyond 60 years of age, and rotation age guidelines developed for red pine in northern and central Wisconsin (within red pine’s native geographic range) do not apply to the management of these stands.

All of the environmental factors causing early decline of red pine stands in southern Wisconsin have not been determined with certainty. Fine textured calcareous soils probably are a major factor. Interactions between climate, insects and diseases, and red pine growth patterns probably also contribute to declines.

Management Recommendations

For established red pine plantations:

- Monitor tree vigor and mortality, and stand growth and productivity
- As long as vigor and productivity are maintained, continue to manage the stand following standard red pine silvicultural guidelines (i.e. intermediate treatments).
- If tree vigor declines significantly, stand-level mortality becomes significant, and/or productivity declines (MAI), then rotate and convert the stand to species more suitable to the site. Early decline is common in red pine plantations cultivated outside of the natural range of red pine in southern Wisconsin.

If considering planting red pine (afforestation or reforestation):

- Evaluate the site and experience with red pine management on similar sites in the area.
- Evaluate the potential to regenerate other species (artificial or natural regeneration) suited to the site and native to the area.

- In general, it is not recommended to establish plantations dominated by red pine outside of the natural geographic range of red pine in Wisconsin.

8 APPENDICES

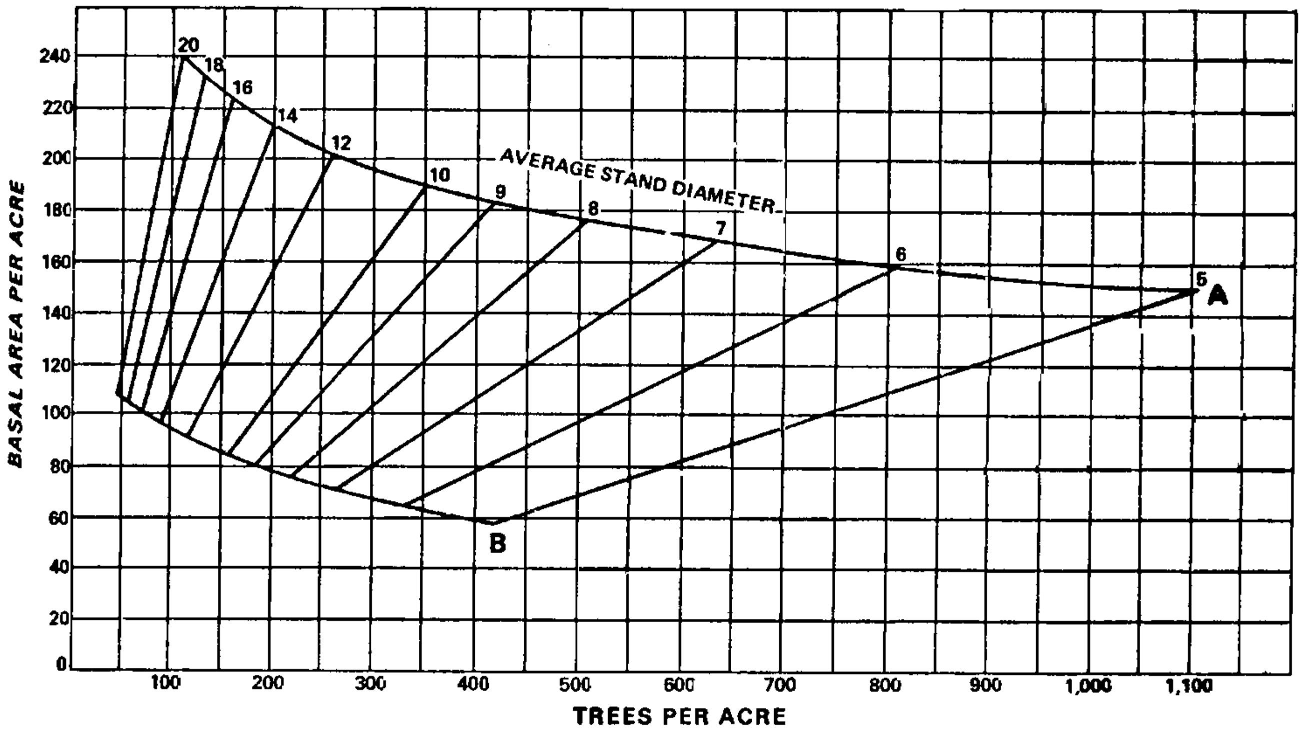


Figure 32.10. Stocking chart for red pine (Benzie 1977).

Stocking chart for red pine, displaying the relationship between basal area, number of trees, and mean stand diameter. The area between the A-line and B-line indicates the range of stocking where trees can fully occupy and utilize the site (fully stocked stand).

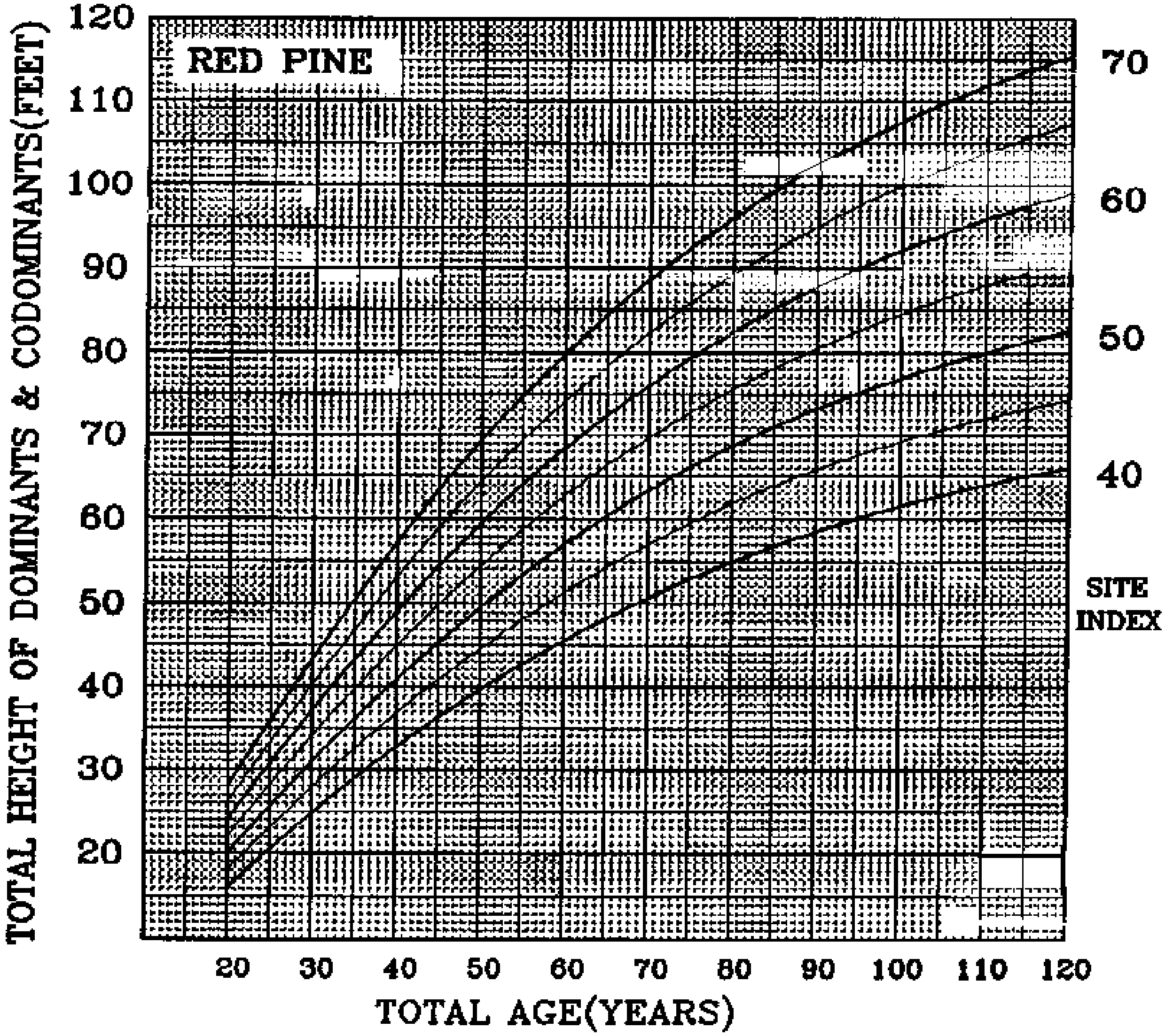
The stocking chart provides a statistical approach to guide stand density management (see Chapter 23).

- To utilize the stocking guide, statistically accurate estimates of at least two stand variables must be obtained, including basal area per acre, number of trees per acre, and/or mean stand diameter.
- The area between the A-line and B-line indicates the range of stocking where optimum stand growth and volume yield can be maintained.
  - The A-line represents maximum stocking. Maintaining stocking levels near (but below) the A-line will produce comparatively more trees, but of smaller diameter.
  - The B-line represents minimum stocking. Maintaining stocking levels near (but above) the B-line will produce larger diameter trees faster, but comparatively fewer trees.

- When designing and implementing a thinning regime for a stand, do not reduce stand density to below the B-line or allow it to surpass the A-line.
- Thinning can occur at any time as long as stand density is maintained between the A-line and B-line. The A-line is not a thinning “trigger.” When to thin depends on management objectives, stand conditions, and feasibility.

Typically, thinning is implemented when average stand stocking is halfway or more between the B-line and A-line. Stocking is reduced to near but above the B-line. A general rule of thumb is do not remove >50% of the basal area in any one thinning operation. Crop tree concepts are applied to retain and focus growth on desirable trees, and order of removal concepts are applied to select which trees will be cut to achieve stand management objectives.

In overstocked stands, thin lightly and frequently, with increasing intensity, for the first several thinnings, to safely develop tree crown vigor and stem strength, and until target residual densities (near the B-line) are achieved.



Red pine (Gevorkiantz 1957c, derived from Eyre and Zehngraff 1948, and Brown and Gevorkiantz 1934)
Minnesota
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: 40 50 60 70+
Years: 8 6 5 4

	b_1	b_2	b_3	b_4	b_5	R^2	SE	Maximum difference
H	1.8900	1.0000	-0.0198	1.3892	0.0000	0.99	0.64	1.4
SI	0.5291	1.0000	-0.019	-1.3892	0.0000	0.99	0.64	1.4

Figure 32.11. Site index curves for red pine (Gevorkiantz 1957, Carmean et al. 1989).

8.1 Forest Health Guidelines - Forest Health Protection (FHP)

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
DEFOLIATING INSECTS		
Pine Tussock Moth – *Dasychira pinicola* Within the hazard zone (Douglas and Bayfield Counties), outbreaks occur every 12-15 years. During outbreaks sapling and pole sized stands can be severely defoliated in spring and early summer. Heavy defoliation of red pine is usually associated with presence of jack pine. Defoliation may cause growth loss, top kill and tree mortality.	Remove adjacent open-grown jack pine. Apply insecticides in spring. Accept defoliation and monitor for tree mortality; harvest if necessary.	
European Pine Sawfly – *Neodiprion sertifer* **Red Pine Sawfly** – *Neodiprion nanulus nanulus* Periodic outbreaks cause spring defoliation of sapling and small pole sized stands. Outbreaks are more severe prior to crown closure and in open-grown stands. Since larvae feed early in the season before new needles develop, current year's	Promote early stand closure. Apply insecticides in spring. Accept defoliation and growth loss.	

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
needles are not defoliated. Heavy defoliation for several years may cause height and radial growth reductions of 80%, but tree mortality is uncommon on healthy trees.		
Redheaded Pine Sawfly – *Neodiprion lecontei* Periodic outbreaks cause severe defoliation of sapling and small pole sized stands in summer. Larvae prefer old needles, however they move to new needles once old needles are consumed. Hazardous conditions: Excessively shallow or disturbed soil Red pine plantation adjacent to hardwood edge Excessive competition from grass or bracken fern Open stand caused by poor initial plantation survival	Prevention Avoid planting on hazardous conditions or monitor plantations closely. Maintain distance (50 feet) from hardwood edge. Control weed and grass competition. If initial survival is poor, replant or interplant. Control of current or impending outbreaks Apply an insecticide to rising populations to prevent major outbreaks. Allow population to increase and apply an insecticide to protect needles.	Redheaded Pine Sawfly-Its Ecology and Management. L.F. Wilson and R.C. Wilkinson. 1992. USDA Forest Service Agriculture Handbook 694. Redheaded Pine Sawfly. L.F. Wilson and R.D. Averill. 1978. USDA Forest Service, Forest Insect and Disease Leaflet 14. http://www.na.fs.fed.us/Spfo/pubs/fidls/pine_sawfly/pinesawfly.htm
Red Pine Needle Midge – *Thecodiplosis piniresinosae* Occasional widespread outbreaks cause needle browning in late summer. The insect attacks trees of	Control is not necessary.	

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
all sizes. However it prefers open-grown saplings of low vigor. Repeated years of heavy attacks may reduce growth and prevent shoot development.		
Jack Pine Budworm - *Choristoneura pinus pinus* Occasional widespread outbreaks cause heavy defoliation. Repeated years of defoliation leads to top dieback and tree mortality. Historically, feeding on red pine was observed only in a mixed stand of jack pine and red pine. However, recently, severe infestations of red pine stands have been observed in central and northern WI.	Accept some loss and monitor stand for budworm population build-up. Cut stands in shapes that minimize the stands' edge areas. Harvest heavily defoliated stands. Apply insecticide, if practical (see on-line manual at right). (The above management options were developed for jack pine. No specific guidelines are currently available for red pine)	How to Manage Jack Pine to Reduce Damage From Jack Pine Budworm. 1994. USDA Forest Service. NA-FR-01-94. http://www.na.fs.fed.us/spfo/pubs/howtos/ht_jack/ht_jack.htm
NEEDLE DISEASES		
Pine Needle Rust – *Coleosporium asterum (syn. C. solidaginis)* The fungus requires an alternate host (aster, goldenrod) to complete its life cycle. Occasionally, it causes needle loss on lower 5 feet of branches during spring. The disease is most prevalent on trees up to sapling size.	Accept some disease occurrence. Do not plant seedlings at close spacing. Remove alternate hosts of the fungus (Aster, Goldenrod) within 300 m of red pines manually or by applying herbicides before August when spores are released.	How to Identify and Control Pine Needle Rust Disease. T.H. Nicholls, et al. 1976. USDA Forest Service.

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
Defoliation may cause growth reduction, although mortality is uncommon.		
Brown Spot Needle Blight - *Mycosphaerella dearnessii* The fungus initially causes brown bands with yellowish margins on needles. Infected needles will later turn brown and prematurely fall in late spring and early summer.	Control is usually unnecessary. Do not plant seedlings at close spacing	Brown Spot Needle Blight of Pines. W.R. Phelps et al. 1978. USDA Forest Service, Forest Insect and Disease Leaflet 44. Brown Spot Needle Blight of Eastern White Pine. 1991. USDA Forest Service NA-PR-03-91.
Needle Droop - caused by drought Drooping and/or browning of needles occur occasionally in drought years. Sandy soil, dense sod and competition for water from other plants increase the risk.	Control weed competition for the first 5-10 years. Plant seedlings properly. Avoid damage to roots such as jamming, and J-rooting.	
BUD, SHOOT AND TWIG INSECTS		
Red Pine Shoot Moth – *Dioryctria resinosella* (see hazard map in FHP Figure 1) Larvae feed on new shoots and kill shoots of trees that are 20 years old and older. Attacks by this insect lead to deformed branches and main	No direct control is available. Remove severely deformed trees during thinning. Consider planting species other than red pine on hazardous sites.	How to identify and minimize red pine shoot moth damage. 1992. USDA Forest Service. NA-FR-02-92. http://www.na.fs.fed.us/SPFO/pubs/howtos/ht_redpine/redpine.htm

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
stems. Trees older than 30 years on dry, sandy soils are most vulnerable to attack.		
European Pine Shoot Moth - *Rhyacionia buoliana* (see hazard map in FHP Figure 1) Larvae feed on buds and shoots. Repeated attacks result in crooked or forked branches and stems. Infestation could last until lowest live branches are above snow line. Open stands are more susceptible to attacks by this insect than closed stands.	No direct control is available. Consider planting species other than red pine on hazardous sites. Prune lower branches.	
Common Pine Shoot Beetle - *Tomicus piniperda* Adult beetles feed on the central portion of the lateral shoots and destroy shoots. Damaged shoots droop, turn yellow to red, and fall. The insect is under federal quarantine (see control column for details).	The insect is native in Eurasia and north Africa and was first discovered in North America in 1992. As of 2008, part or all of 18 states are under federal quarantine for this insect, including the entire state of Wisconsin. For information about quarantine regulations when pine materials are shipped from Wisconsin to non-quarantined states, visit http://www.aphis.usda.gov.	Pest alert: New Introduction - Common Pine Shoot Beetle. USDA Forest Service NA-TP-05-93. http://www.na.fs.fed.us/spfo/pubs/pest_al/shootbeetle/shootbeetle.htm

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
Saratoga Spittlebug - *Aphrophora saratogensis* Sapsucking injury causes twig flagging, reduced tree growth, stem deformity, and branch mortality. Tree mortality occurs when severely infested. Trees up to 15 feet tall are more susceptible to attacks. When population is high, plantation failure could occur.	Avoid planting red pine in frost pockets, swales, and any other low lying areas. Remove alternate hosts of Saratoga spittlebug (sweet fern, young willow, berry bushes, etc.) when they occupy 20% or more of the ground cover. Monitor for Saratoga spittlebug populations and treat with insecticides if necessary. Monitor for the existence of flagged volunteer jack pine in a stand as flagging symptoms often begins one year ahead of red pine during outbreaks.	Saratoga Spittlebug-Its Ecology and Management. L.F. Wilson. 1987. USDA Forest Service Agriculture Handbook No. 657. Saratoga Spittlebug. L.F. Wilson. 1978. USDA Forest Service. Forest Insect & Disease Leaflet 3. http://www.na.fs.fed.us/spfo/pubs/fidls/saratoga/saratoga.htm
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 root collar areas of seedlings and causes seedling mortality. Understory red	Maintain tree vigor. Do not prune trees during wet periods. Avoid two-story or uneven-aged stands in areas with a history of serious Diplodia infection. Remove infected overstory and windbreak pines. Avoid planting red pine on dry sites or sites that have a history of serious Diplodia infection. If more than 50% of the crown is affected, consider salvage harvesting.	Diplodia Blight of Pines. G.W. Peterson. 1981. USDA Forest Service. Forest Insect & Disease Leaflet 161. http://www.na.fs.fed.us/spfo/pubs/fidls/diplodia/diplodiafidl.htm How to Identify and Control Diplodia Shoot Blight, Collar Rot, and Canker of Conifers. 1983. USDA Forest Service. http://www.na.fs.fed.us/spfo/pubs/howtos/ht_conifers/ht_conifers.htm

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
pine near older diseased red pine or windbreak pines are likely to be infected by falling spores.		
Sirococcus Shoot Blight (Red pine shoot blight) - *Sirococcus conigenus* (see FHP Figure 1 for the county distribution of this disease) 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 could kill seedlings and repeated infections could kill saplings. Understory red pine near older diseased red pine or windbreak pines are likely to be infected by falling spores.	Do not prune trees during wet periods. Avoid two-story or uneven-aged stands in areas with a history of serious Sirococcus infection. Remove infected overstory and windbreak pines.	Sirococcus Shoot Blight. T.H. Nicholls. 1984. USDA Forest Service. Forest Insect & Disease Leaflet 166. http://www.na.fs.fed.us/spfo/pubs/fidls/sirococcus/sirococcus.htm

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
Scleroderris Canker - *Gremmeniella abietina* (see FHP Figure 1 for the county distribution of this disease) Infected needles turn orange at the base in spring and later turn brown and fall off. The fungus moves to branches and main stems to develop a canker. 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.	Within hazard zone, avoid planting red pine and jack pine in frost pockets, areas of depressed ground where frost conditions are greater earlier and later in the season. Remove all infected red and jack pine.	How to Identify Scleroderris Canker. D. D. Skilling and J.T. Obrien. 1979. USDA Forest Service. Scleroderris Canker of Northern Conifers. D.D. Skilling et. al. 1979. Forest Service. Forest Insect & Disease Leaflet 730. http://www.na.fs.fed.us/spfo/pubs/fidls/scleroderris/scleroderris.htm Biology and Control of Scleroderris Canker in North America. D. D. Skilling et. al. 1986. USDA Forest Service. Research Paper NC-275.
CANKER ROT DISEASE		
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, hard, and bracket or hoof shape with irregular margins. Upper surface is dark grayish to dark brown.	Remove infected trees during thinning. Minimize injuries during logging operations.	Canker-rot fungi and cankers of Northern Hardwoods. 2004. Wisconsin DNR. Division of Forestry.

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
MAIN STEM/ROOT INSECTS		
Northern Pine Weevil - *Pissodes approximates* Severe feeding by the adults may kill some shoots. This insect could cause considerable mortality in 1-5 year-old red pine plantations.	Delay planting seedlings for 2 years after harvesting pines. Remove freshly cut pine stumps before planting seedlings, if practical (rarely practical). Treat freshly cut stumps with an insecticide if practical (rarely practical).	A guide to Insect Injury of Conifers in the Lake States. USDA FS Agriculture Handbook No. 501
Pales Weevil - *Hylobius pales* Weevils kill seedling stems and young shoots of older trees by removing a complete ring of bark around stems or twigs. It kills first-year seedlings during moderate infestations. It can kill seedlings up to 3 years of age during heavy infestations. Though it also attacks older trees, the damage is minimal.	Delay planting seedlings for 2 years after harvesting pines. Remove freshly cut pine stumps before planting seedlings, if practical (rarely practical). Treat freshly cut stumps with an insecticide if practical (rarely practical).	A guide to Insect Injury of Conifers in the Lake States. USDA FS Agriculture Handbook No. 501 Pales Weevil. J.C. Nord, I. Ragenovich, and C.A. Doggett. 1984. USDA For. Serv. Forest Insect and Disease Leaflet 104. http://www.na.fs.fed.us/spfo/pubs/fidls/pales/fidl-pales.htm
Pine Root Collar Weevil - *Hylobius radices* Feeding under bark at root collar areas causes mortality of sapling and small pole-sized trees. Trees may tilt or break off at the root collar. Trees	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.	See Red Pine Pocket Mortality below

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
planted on nutrient-deficient, sandy soils, trees with their root collars 3 inches or more below the soil surface, and red pine stands within a half mile of heavily infested Scotch pine are more prone to weevil infestation. Trees growing in open stands are more vulnerable to weevil attacks than closed stands. The insect is considered to be one of the vectors that transmits Leptographium spp. (see Red Pine Pocket Mortality) Infestation is suspected by the existence of black pitch-encrusted areas around the bole right below the ground line. Infested trees may have declining upper crowns and excessive taper.	Avoid planting red pine within one mile of infested Scotch pine stands. Liquidate nearby abandoned Scotch pine Christmas tree plantations.	
Pine root tip weevil - *Hylobius rhizophagus* Feeding on roots causes flagging, top kill and tree mortality in pole-size pines. Moderate weevil damage reduces tree growth. Red pine stands that are near Scotch pine are more vulnerable to weevil attacks. Infestation is often associated with	Accept some damage and loss. Remove jack pine from infested red pine stands. Harvest merchantable trees when branches start to die. Liquidate nearby abandoned Scotch pine Christmas tree plantations.	Life History and Damage of the Pine Root Tip Weevil, Hylobius rhizophagus in Wisconsin. W.H.Kearby and D. M. Benjamin. Annals of the Entomological Society of America. 1969. Vol. 62, No. 4, p838-843.

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
presence of jack pine and/or nutrient-deficient, sandy soil.		
White Grubs - *Phyllophaga spp.* Feeding on roots kills seedlings established for 1-3 years on sandy soils. White grub densities above 0.2 per square foot may cause heavy seedling mortality and stunting of surviving seedlings. They are common on grassy or weedy sites.	Survey stands for white grub population before planting. If the population density is high, delay planting for one to two years. Currently, there is no insecticide clearly labeled for forestry use against this insect.	White Grubs, Phyllophaga spp. D. Hall. Wisconsin DNR, Division of Forestry.
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 oak as an alternate host to complete its life cycle and it 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, Lincoln Cos.). The	Remove severely infected trees and branches during thinning. Examine seedlings for galls or swelling on main stems, branches, and root collar areas before planting. Do not plant symptomatic seedlings.	The Range of Western Gall Rust in Wisconsin. W.T. McGrath and R. F. Patton. 1969. Plant Disease Reporter Vol. 53 No. 5 p357-359.

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
fungus causes swollen spherical galls on pine twigs, branches and main stems. Galls kill seedlings and branches of older trees. The disease is very common on jack pine near oaks.		
ROOT DISEASE		
Armillaria Root Disease (Shoestring root rot) – *Armillaria spp.* Girdles roots and lower trunks, causing cankers as well as stringy white rot. Growth reduction and yellowing needles are symptoms, and 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.	Maintain stand in healthy condition. Harvest declining trees before bark beetle infestation, mortality, and decay take place.	Armillaria Root Disease. R. Williams, et al. 1986 USDA Forest Service, Forest Insect and Disease Leaflet 78.
ROOT DISEASES/DISEASE COMPLEX		
Annosum Root Rot - *Heterobasidion annosum*	Expect tree mortality in pockets and growth loss in trees around the pocket margin.	Annosum Root Rot and Red Pine Pocket Mortality in Wisconsin; Biology and Management. 2008. Wisconsin DNR, Division of Forestry.

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
In Wisconsin, the disease was first confirmed in Adams Co. in 1993. As of July 2009, the disease is confirmed in 20 Counties (see FHP Figure 1 for the county distribution of this disease). Infection causes pockets of trees to develop thin crowns, reduced growth, and tree mortality. Crown symptoms typically appear 2-3 years after thinning. Pockets expand at about ½ to 1 chain every 10 – 15 years. Fruiting bodies develop at the base of infected trees. They are white and look like popcorn at an early stage, and under favorable conditions, they develop into a perennial bracket-shaped conk. A new infection site usually originates at cut stumps by spores landing on them. The fungus also spreads through root contact.	Dead trees and the bottom 8 feet of trees that are showing dieback should be left on site during thinning to avoid inadvertent disease spread. Pre-salvage healthy trees 1/2 to 1 chain outside pocket perimeters to utilize the wood before the trees die. Prevention During thinning and harvesting, start in healthy stands or areas and work in diseased areas last. Apply a registered fungicide on fresh cut stumps as soon as possible after cutting or by the end of each day. Currently the use of fungicide is recommended year round throughout the state of Wisconsin. Clean logging equipment with pressurized water before leaving diseased stands.	http://dnr.wi.gov/forestry/fh/annosum/pdf/AnnosumRPPM.pdf Annosus Root Rot in Eastern Conifers. K. Robbins. 1984. USDA Forest Service Forest Insect & Disease Leaflet 76.
Red Pine Pocket Mortality Caused by a complex of insects, fungi (*Leptographium spp.)* and insect fungal vectors. Trees weakened by root insects and fungi are later killed by bark beetles (Ips spp.) This complex was first identified in	Leave the pocket as a natural opening. Cut dead trees and trees that are showing dieback and/or yellowing of the foliage within and adjacent to the pocket. Cut dead trees and trees that are showing dieback and/or yellowing of	Annosum Root Rot and Red Pine Pocket Mortality in Wisconsin; Biology and Management. 2008. Wisconsin DNR , Division of Forestry http://dnr.wi.gov/forestry/fh/annosum/pdf/AnnosumRPPM.pdf

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
Wisconsin in 1975. Infected trees have reduced growth and thin crowns with yellowing, tufted needles. Pockets typically start small with one to a few dead trees surrounded by trees that have reduced shoot growth and thin crowns. Each year, a few trees on the pocket edge may die and the edge of the pocket expands. *Leptographium spp*. moves below ground through root contact and the pocket expands about 1 chain every 10 – 15 years.	the foliage, and also cut a buffer area of healthy trees around the pocket to utilize the wood before they die. There are some experimental management options. For the experimental options, please refer to the referenced management guide.	
ANIMAL DAMAGE		
Meadow Mouse (Meadow Vole, Field Mouse) Gnawing on bark at the base of trees during winter results in mortality of trees up to 8 years old. Dense grass supports population build-ups which may cause heavy mortality.	Remove grass before planting. Control grass within 3 feet of young trees. Keep grass mowed. Practice green, cavity, and snag tree retention.	Meadow Mouse Control. Scott Craven. 1981. Univ. Wisc. Ext. Leaflet A2148.
Pocket Gophers In western Wisconsin, feeding on roots, results in mortality of seedlings and saplings. Significant mortality occurs where two or more gopher	Accept the risk of some mortality. Eliminate gophers with rodenticide, trapping, or shooting. Practice green, cavity, and snag tree retention.	Pocket Gophers. R. M. Case. 1983. Univ. Nebraska Ex. Pocket Gophers in Forest Ecosystems. C. L. Teipner, et. al. 1983. USDA Forest Service Gen. Tech. Rep. INT-154.

Disturbance Agent and Expected Loss or Damage	Prevention, Options to Minimize Losses, and Control Alternatives	References*
mounds per acre are present. Look for trees tilting at odd angles in 3-8 year-old plantings. Such trees can be pulled up with almost no efforts as they have been rendered rootless by gopher feeding.		
Rabbits/Hares Mortality through stem girdling due to feeding on the bark.	Control is usually unnecessary.	Rabbit Damage to Tree Plantings.

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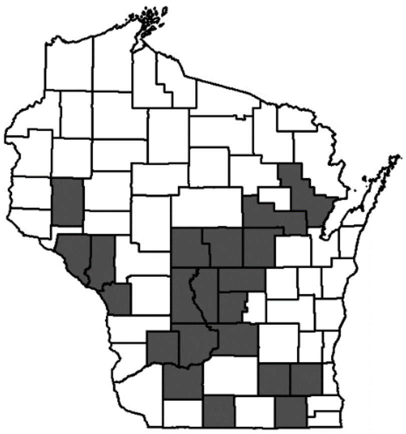
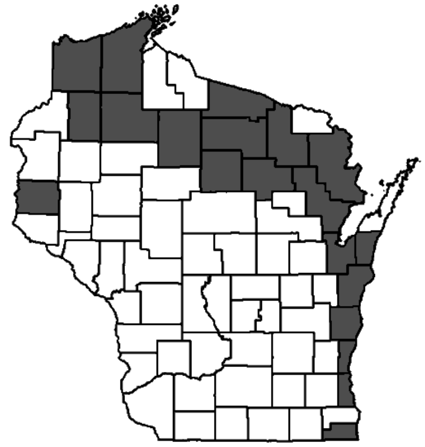
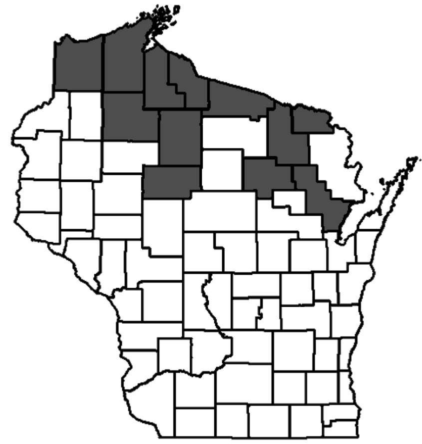


Counties confirmed with Annosum root rot

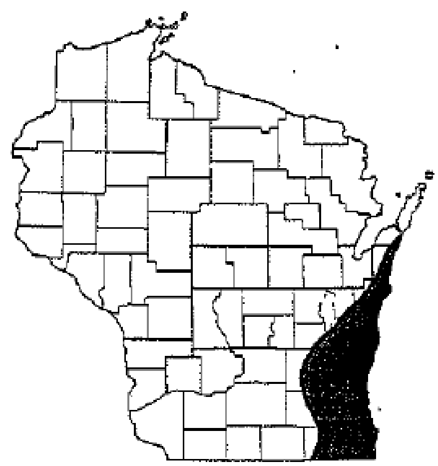


Counties where *Sirococcus* sp. was reported on conifers (Hosts include pines, spruces, and firs)



Counties confirmed with Scleroderris canker

Red pine shoot moth Hazard zone in Wisconsin



European pine shoot moth Hazard zone in Wisconsin

Figure 31.12. County distribution/hazard maps for several pests on red pine

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