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Ecological Silviculture for Great Lakes Red Pine Ecosystems

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2.1 Introduction

Red pine (*Pinus resinosa* Ait.) ecosystems of the western Great Lakes region of United States and Canada are the focus of this chapter. These forests are found in northern Michigan, Wisconsin, and Minnesota in the United States, and portions of southern Ontario, Canada (Figure 2.1).

Historically, because of high economic value of red pine, this ecosystem has been managed using a timber-focused silvicultural system in both plantations and natural-origin stands, generally based on even-aged regeneration systems followed by planting of red pine. The timber-focused model results in composition and structure that deviate substantially from the natural model, favoring high tree densities, monospecific composition, a narrowly even-aged structure, limited structural complexity (see Chapter 1), and rotations of 50–90 years [1]. As a consequence, approximately 76% of red pine-dominated forests in the United States Lake States are plantations [1].

Interest has grown in silvicultural approaches that better reflect the natural model of disturbance and development for this ecosystem, i.e. ecological silviculture; such approaches can be used to transition plantations and simplified natural forests to structurally complex and diverse conditions that better reflect the native ecosystem condition. There is limited experience with actual ecological silviculture approaches for red pine; this chapter provides a framework for developing these approaches.

2.2 Characteristics of Red Pine Ecosystems

2.2.1 Composition and Structure

There are many variants of red pine ecosystems across the region, but broadly we are considering ecosystems where red pine, often with eastern white pine (*Pinus strobus* L.), is the dominant species. This said, these ecosystems are actually better characterized as having mixed-species composition, potentially containing up to 12 tree species (Table 2.1). The species differ in shade tolerance and life span, but most establish on mineral soil, reflecting adaptation to post-fire environments. The species are present in varying abundance depending on the specific variant of the ecosystem and the stage of development.

Ecological Silvicultural Systems: Exemplary Models for Sustainable Forest Management,
First Edition. Edited by Brian J. Palik and Anthony W. D'Amato.

Figure 2.1 Distribution of red pine in the western Great Lakes region of North America. *Source:* commons.wikimedia.org.

Table 2.1 Silvical characteristics of tree species found in Great Lakes red pine ecosystems.

Common name	Species	Shade tolerance	Preferred seed bed	Maximum reported age (years)
Balsam fir	*Abies balsamea* (L.) Mill.	Very tolerant	Moist mineral	245
Bigtooth aspen	*Populus grandidentata* Michx.	Very intolerant	Moist mineral	113
Trembling aspen	*Populus tremuloides* Michx.	Very intolerant	Moist mineral	213
Black spruce	*Picea mariana* (Mill.) Britton, Sterns & Poggenb.	Tolerant	Moist mineral/organic	330
Bur oak	*Quercus macrocarpa* Michx.	Intermediate	Mineral	401
Eastern white pine	*Pinus strobus* L.	Intermediate	Moist mineral	408
Jack pine	*Pinus banksiana* Lamb.	Very intolerant	Moist mineral	246
Northern red oak	*Quercus rubra* L.	Intermediate	Moist mineral with litter	326
Paper birch	*Betula papyrifera* Marshall	Intolerant	Moist mineral	240
Red maple	*Acer rubrum* L.	Tolerant	Litter	300
Red pine	*Pinus resinosa* Ait.	Intolerant	Moist mineral	500
White spruce	*Picea glauca* (Moench) Voss	Tolerant	Moist mineral	262

Sources: Wisconsin Department of Natural Resources [24] and Rocky Mountain Tree-Ring Research, Inc. and The Tree-Ring Laboratory of Lamont-Doherty Earth Observatory and Columbia University [25]. Modified from and reprinted by permission of Waveland Press, Inc. from Palik et al. [1],

Figure 2.2 Old-growth red pine forest: northern Minnesota, USA. Note multiple tree species, dead wood, and diversity of tree sizes. *Source:* With permission from Shawn Fraver.

Age structures of natural origin red pine ecosystems range from broadly single-cohort to two- or three-cohort [2]. Stands are characterized by high levels of structural complexity and heterogeneity (Figure 2.2). Mature and old stands are characterized by woodland structure, with open and variable canopies and low tree densities [3]. Younger developmental stages can be structurally complex, containing substantial legacies of a pre-disturbance forest, including live trees and large deadwood (Chapter 1).

2.2.2 Natural Disturbance Regime

The natural disturbance regime for red pine ecosystems is largely characterized by wildfire. The fire regime is complex, including frequent surface fires punctuated by infrequent crown fires. Historically, the mean combined surface/crown fire return interval has been estimated to range from less than 10 years up to 25 years [4, 5]. The variation in the return interval may reflect burning activity of indigenous peoples, with shorter return intervals associated with higher population areas [6]. Lightning is also a source of ignition [7], but it is unclear if lightning ignitions were/are frequent enough to generate the shortest fire return intervals noted.

Surface fires periodically intensified to kill canopy trees, but mortality was often less-than-stand replacing, as evidenced from reconstructions of tree establishment in old-growth stands [2, 8], as well as many early descriptions of this ecosystem (e.g. [9]). New pine cohorts established in moderate to large openings within stands. True stand-replacement fires occurred [10] but with red pine establishment periods potentially lasting decades. Historically, some red pine ecosystems contained abundant overstory oaks (*Quercus* spp.) [11, 12]. This likely occurred where surface fire intervals were protracted or fires were patchy, allowing these species to avoid fires while of a susceptible size. The natural fire regime is augmented by patch-scale tree mortality from wind and

Armillaria fungi [10, 13]. These disturbances can be important drivers of variation in stand structure and composition, such as hardwoods versus conifers.

2.2.3 Natural Development Model

The natural development model for red pine ecosystems is presented in detail elsewhere [1]; here we present an updated and abbreviated version of the model (Table 2.2). The model begins with a canopy disturbance and proceeds through young, mature, and old forest stages.

2.2.3.1 Disturbance and Legacy Creation

After a canopy disturbance, red pine ecosystems will contain live tree legacies and abundant deadwood structures. Live tree legacies vary from few after severe disturbance to abundant after partial disturbance. Spatial patterns vary from dispersed to aggregated or the pattern may occur as large openings within a less disturbed matrix. Large snag and dead tree legacies will mostly be red and eastern white pines, as these are the dominant species, but other species of deadwood will be present.

2.2.3.2 Preforest Stage

A preforest stage (Chapter 1) is dominated by herbs and shrubs. It may range from a few years, if there is aggressive sprouting of hardwoods (Figure 2.3), or if pines establish after a mast seed year, to decades. Evidence for a several decades-long preforest stage is the often-slow establishment of pines after disturbance (see below).

Table 2.2 A developmental model of red pine ecosystems.

Stage or event	Attribute	Cause or consequence
Disturbance and Legacy Creation	Live trees and deadwood legacies; dispersed to aggregated spatial patterns	Near stand replacing to partial canopy disturbance
Preforest Stage (*Locally absent to one-several decades*)	Herb/shrub dominated; tree regeneration present but not controlling the site	Non-forest organisms and processes dominate; sprouting of hardwoods may shorten length
Young Forest Stage (*Lasting 50–70 years*)	New pine cohort establishes, often in mixtures with other species	Pine establishment may last 40–70 years; densities of regenerating pine may increase slowly; tree species mixtures develop
Mature Forest Stage (*Lasting 50–100 years*)	Red pine and often eastern white pine dominate; shorter-lived species decline; dead and decadent trees accumulate; canopy heterogeneity develops	Patchy fire creates openings for pine establishment; recruitment of fire-sensitive species may occur in fire skips; root-rot gaps are foci for hardwood establishment; small-scale disturbance increases heterogeneity
Old Forest Stage (*Begins after ~150 years*)	Dominated by old emergent pines; broadly even-aged to two+ cohorts; patchy canopy; abundant dead wood; pine regeneration in openings; other canopy species present	Pines accumulate complex morphologies; patchy disturbance creates heterogeneity, fosters tree diversity, and pine establishment

Source: Palik et al. [1]/Reproduced with permission from Waveland Press, Inc.

Figure 2.3 Trembling aspen root suckering in an opening of a mature red pine forest. *Source:* With permission from Christel Kern.

2.2.3.3 Young Forest Stage

In the young forest stage, regenerating trees begin to take control of a site, but this may occur over decades, for example up to 60–70 years [2]. This can occur across whole stands, or it may be focused within larger openings with less-severe disturbance. Tree dominance in the young forest stage may be shared between red pine and other intolerant species, including aspens (*Populus* spp.), paper birch (*Betula papyrifera* Marsh.), and jack pine (*Pinus banksiana* Lamb.).

2.2.3.4 Mature Forest Stage

The mature forest stage is characterized by increasing abundance of eastern white pine, northern red oak (*Quercus rubra* L.), and red maple (*Acer rubrum* L.), along with red pine. These species may be present early after disturbance, but they gain abundance slowly below the red pine canopy. The additional species rarely replace red pine, under a natural fire regime, but historically they often were abundant in older stands [11, 12]. The mature forest stage may also have a spatially heterogeneous canopy structure, developing after patchy disturbances. New cohorts of red pine may establish in larger openings [2].

2.2.3.5 Old Forest Stage

Old forests are structurally complex, with large old trees, diverse tree sizes, and abundant large deadwood. Old pines develop complex morphologies, with large diameters and branch systems, broken tops, and cavities. Snags and downed logs will be equally large. Canopy heterogeneity develops from patchy disturbance. Emergent red pine may co-occur with other species in the main canopy, including eastern white pine, northern red oak, and red maple. Early successional aspens, paper birch, and jack pine can maintain a presence with establishment in larger gap disturbances.

2.2.3.6 The Cycle of Disturbance and Development

Depending on spatial extent of a canopy disturbance, stands in the mature or old-forest stages may continue to develop into yet older conditions, or they may cycle back to the beginning of the development model, i.e. with a new disturbance and legacy creation event. However, given that the latter disturbances are often less than stand-replacing, the structural condition consists of openings, initiating a preforest stage and ultimately a new cohort of trees, as well as residual individuals and clumps of trees from the previous stand, resulting in a multi-cohort age structure.

2.3 An Ecological Silvicultural System for Red Pine Ecosystems

An earlier version of our ecological silvicultural system, based on the natural development model presented above, has been presented elsewhere [1]; here we present a revised version of the approach (Table 2.3). In most cases, actions will be applied at the whole-stand scale, however, as stands develop, some actions might be applied at patch scales within a stand. In general, the system is applicable to both natural origin and plantation stands.

Table 2.3 An ecological silvicultural system for red pine ecosystems.

Stage[a]	Years[b]	Potential actions	Outcomes
Disturbance/ Legacy Creation[c]	0	Variable retention harvest (VRH) Creation of down deadwood and snags Site preparation to reduce slash, expose mineral soil	Continuity of structure; initiate a preforest stage
Preforest	1–20+	Reduce overabundant shrubs Site preparation as needed	Herb/shrub dominated
Young Forest (early)	5–30	Plant, seed, capture mast seed crop Release natural regeneration	Establish a new tree cohort
Young Forest (later)	30–70	Crop-tree release; Variable density thinning (VDT)[d] In VDT gaps: expose mineral soil, reduce shrubs, regenerate trees	Increase growth; enhance canopy heterogeneity; may initiate preforest or new cohort in openings
Mature Forest	70–150	Crop-tree release or VDT in even-aged stands or in younger cohort of two-cohort stands[d] In new VDT gaps: expose mineral soil, reduce shrubs, regenerate trees Existing VDT gaps: expand, site preparation, regenerate, competition control Decadence/deadwood creation Reduce aggressive shrubs and fire-sensitive hardwoods Variable retention harvest	Increased tree growth; enhanced heterogeneity; enriched tree species; may initiate preforest or new cohort in VDT openings or cycle stand back to *Disturbance and Legacy Creation*

Table 2.3 (Continued)

Stage[a]	Years[b]	Potential actions	Outcomes
Old Forest	+150	Decadence/deadwood creation VDT in dense standsd New VDT gaps: expose mineral soil, reduce shrubs, potentially regenerate Existing gaps: expand, site preparation, regenerate, competition control Reduce aggressive shrubs and fire-sensitive hardwoods	Enhanced structural complexity and heterogeneity, enriched species diversity, restored woodland structure

[a] Harvest initiates the developmental sequence, or in existing stands, the table is entered according to current developmental stage, and actions are applied from that point onward.
[b] Timing reflects a general length of time that a particular stage might last.
[c] In the context of a managed forest, legacy creation includes retention of from the pre-disturbance forest and creation of new deadwood.
[d] VDT that includes larger gaps may initiate a disturbance/legacy event in the gap and return to time zero in the context of the gap, but not the whole stand; in the gap, preforest and early young forest conditions and actions may apply.
Source: Palik et al. [1]/Reproduced with permission from Waveland Press, Inc.

2.3.1 Disturbance and Legacy Creation

An initial focus of a regeneration-scale harvest is retention of legacies, including live trees and deadwood, in conjunction with creating resource and seedbed conditions necessary for the eventual establishment of a new cohort of trees. It may also include creation of deadwood if this is lacking. The harvest will also initiate a preforest stage. Natural regeneration may establish early after disturbance, but the goal may not be full site occupancy of regeneration early, as that may undermine the ecological value of a preforest stage.

A variable retention harvest (VRH; Chapter 1) will be used to initiate this stage (Figure 2.4). Live tree retention may range from few to many individuals in dispersed to aggregated patterns. Openings might be the dominant matrix condition, or the pattern may consist of patch cuts within forested matrix that is thinned or unthinned. Existing large deadwood should be retained, and some deadwood may be created to emulate the legacies of disturbance. Note that disturbance and legacy creation may also be a feature of larger openings cut as part of variable-density thinning (VDT; Chapter 1).

2.3.2 Preforest Stage

Most foresters will have little experience managing for a preforest stage, often because they have time-sensitive requirements for regeneration, e.g. fully stocked within five years. With planning, a preforest stage can still be included. For example, artificial regeneration can be deferred for five years, or it can be added in stages over five years, much like natural regeneration accumulates in some settings. When early full-site stocking of regeneration is not a constraint, regeneration can be added over time or natural regeneration can be used exclusively to extend the preforest stage.

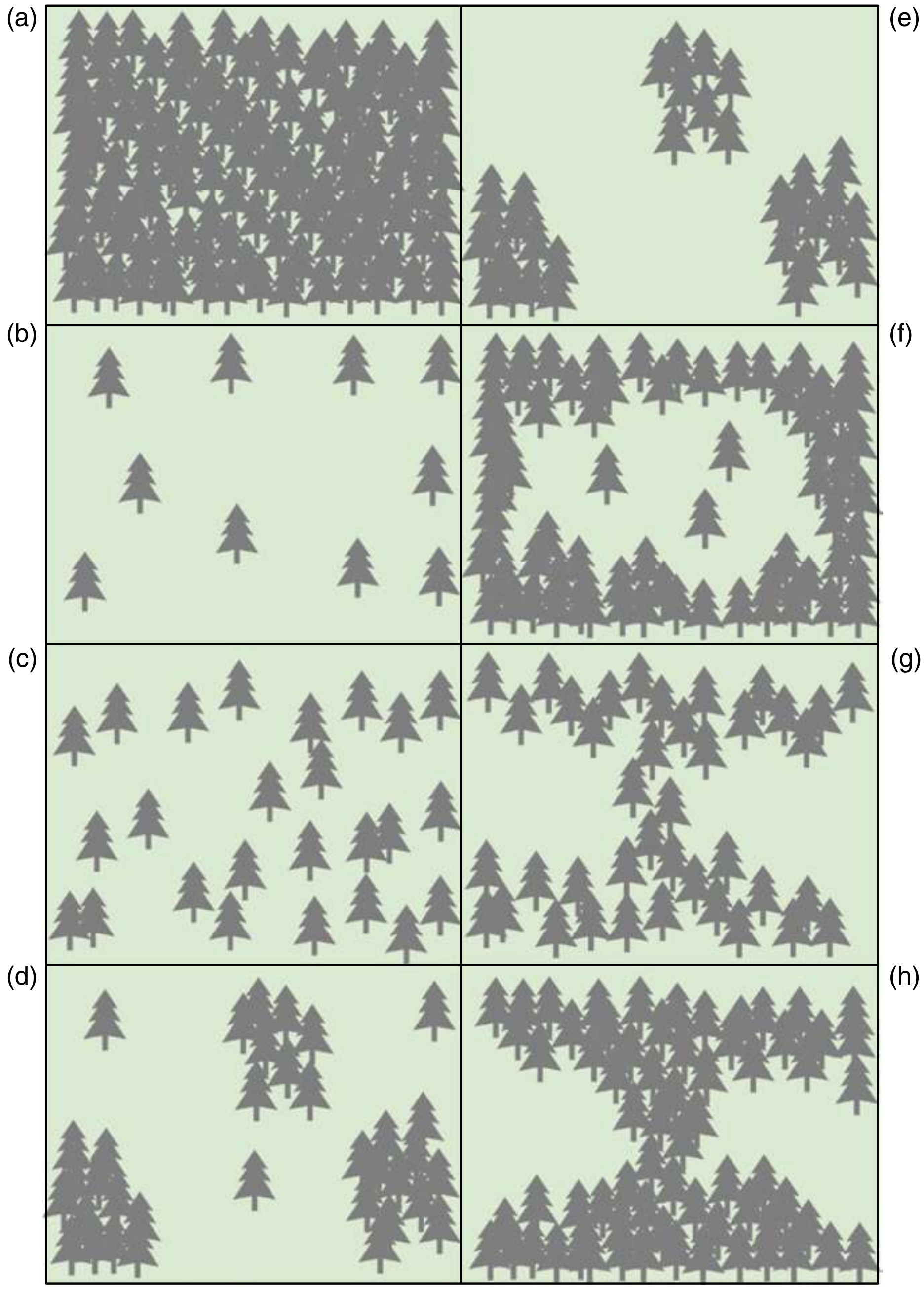

Figure 2.4 Examples of variable retention harvesting in red pine stands: (a) uncut stand, (b, c) dispersed retention, (d, e) patch retention with or without retention between patches, (f) large opening with retained trees, (g, h) large openings with and without thinning in the matrix. *Source:* Palik et al. [1]/Reproduced with permission from Waveland Press, Inc.

Silvicultural actions during a preforest stage may include site preparation and control of aggressive shrubs. While some exposure of mineral soil may occur with harvesting, additional site preparation might be needed to increase establishment from seed, particularly of pines, or to add planting microsites. Competition control may be needed during the preforest stage, particularly to control invasive shrubs, including hazels (*Corylus* spp.) and raspberries (*Rubus* spp.). Site preparation and competition control might be accomplished with prescribed fire or mechanical methods.

Area-wide application of site preparation should be avoided to protect already established tree regeneration, other vegetation, and large deadwood.

2.3.3 Young Forest Stage (Early)

Silviculture in young stage stands focuses on ensuring establishment of a new cohort of trees. This may be natural regeneration that started to develop in the preforest stage, including sprouting hardwoods or species establishing from seed. Natural regeneration may be supplemented with artificial regeneration, but ideally not replaced by it. Ensuring adequate regeneration may require site preparation if it is not sufficient at this point. Planted species likely will include red pine, jack pine, and eastern white pine. In an ecological system, planting densities will be at the lower range of, or below, those typically recommended with a timber-focused approach (typically 1000–2500 trees ha^{-1}). Mechanical release of established regeneration may be needed.

2.3.4 Young Forest Stage (Later)

Competition control around developing regeneration may be needed in this stage. This may include thinning established cohorts of trees using a crop-tree release and/or variable-density thinning (VDT). Thinning might be applied to an even-aged stand, or to a younger cohort in multi-cohort stands if such exists (Figure 2.5). An initial thinning might be pre-commercial, but eventually, it will be applied to merchantable trees. Subsequent thinning entries should be applied to maintain or augment the heterogeneity of density developed in an initial thinning. The length of the young forest stage is such that two or three thinning entries on a

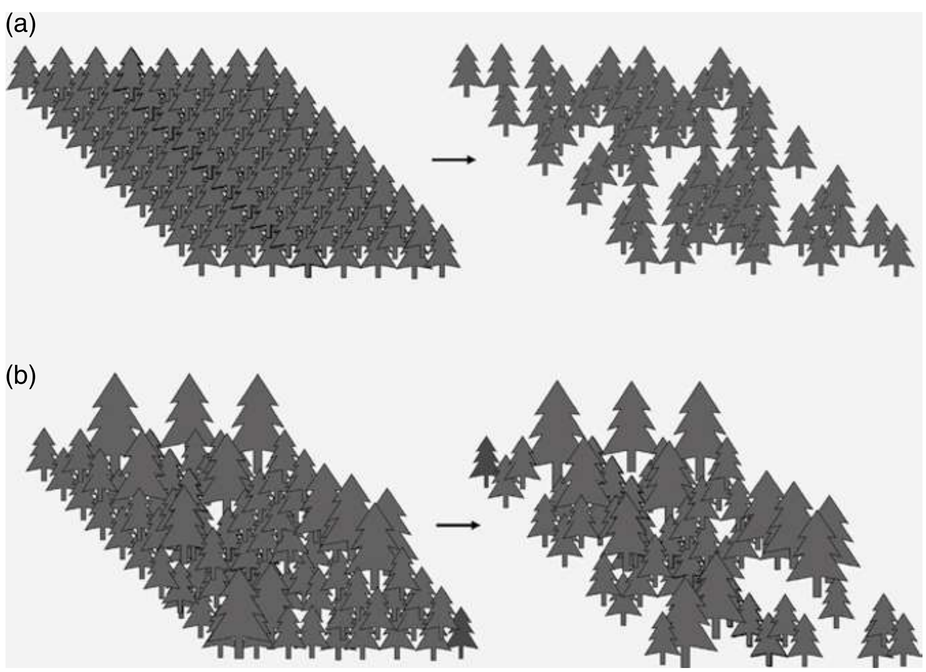

Figure 2.5 An example of variable-density thinning (VDT) in a young forest stage red pine stand. (a) VDT in an even-aged stand. (b) VDT of the younger cohort in stands with two cohorts. *Source:* Palik et al. [1]/ Reproduced with permission from Waveland Press, Inc.

10–15-year interval are possible. If thinning includes cutting larger gaps as part of VDT, then there may be a need for site preparation, regeneration, and competition control in the openings (as above).

2.3.5 Mature Forest Stage

There are two silvicultural pathways to consider in mature-stage stands, including transitioning to an increasingly older condition or cycling back to the start of the development model with a harvest. The pathways are not mutually exclusive; transition treatments may include creation of some larger openings that trigger a preforest stage within the opening.

The first pathway likely includes VDT, either as a first entry or building on an earlier VDT (Figure 2.6). Objectives for a second VDT likely will include releasing established regeneration and crop trees. New gaps might be created in areas with desired advance regeneration or may require site preparation and regeneration (eventually). Prescribed fire or other treatments might be used to reduce aggressive shrubs and fire-sensitive hardwoods in new gaps and the matrix, while avoiding established pine regeneration in older gaps. A VDT in the mature stage presents opportunities to diversify tree species composition. This could focus on VDT gaps, or the matrix for more shade-tolerant species. Deliberate deadwood and decadence creation might be pursued in stands that lack these structures. If repeated VDT entries are used, this pathway emulates the development into complex, multi-cohort, age structures found in some natural stands.

The second silvicultural pathway uses a VRH that retains structural elements, including trees that continue to develop, and deadwood. As above, tree retention may range from low to moderate density in dispersed or aggregate patterns, or large gap/intact matrix retention (Figure 2.4). Deliberate deadwood and decadence creation might be included as part of a VRH.

With the second pathway, actions will be taken eventually to secure regeneration (as above). In doing so, the pathway will emulate the two-cohort age structural development characteristic of many natural stands. Creative prescriptions might be needed to secure this second cohort due to

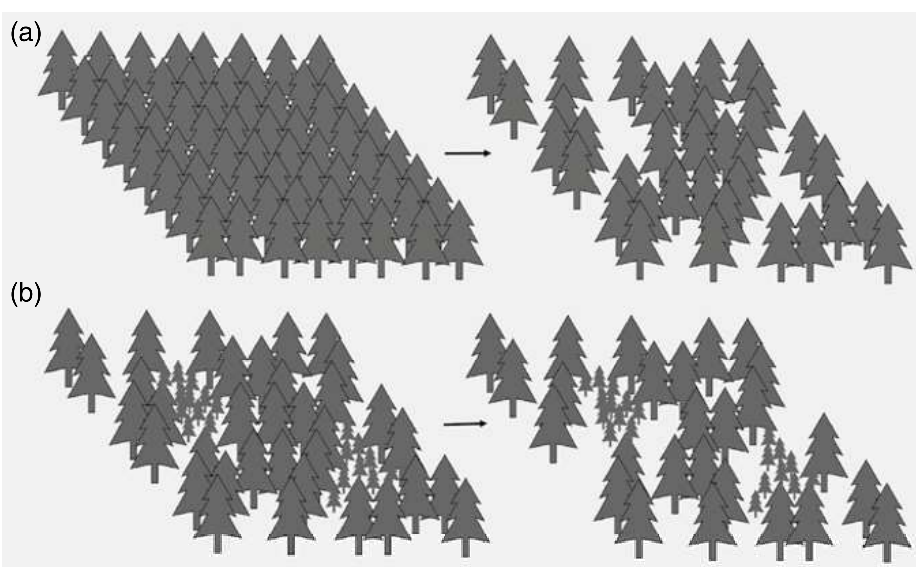

Figure 2.6 Variable-density thinning (VDT) in a mature stage red pine stand. (a) Stand before and after an initial VDT. (b) Thinning that builds on an earlier VDT by expanding gaps, releasing a younger cohort of trees, and thinning the matrix. *Source:* Palik et al. [1]/Reproduced with permission from Waveland Press, Inc.

the impacts of shoot blight diseases including *Sirococcus conigenus* and *Diplodia pinea*. Red pine is susceptible to mortality from these fungal pathogens, particularly when growing near infected overstory trees [14]. However, survival is higher in larger openings [15], as would be present with VRH. Moreover, infection may be minimized with alteration of the dominant pines, so as to prevent red pine dominance in both the overstory and regeneration layers at the same time. For instance, a VRH might retain mostly red pine, followed by regeneration of eastern white pine, jack pine, and oaks. A subsequent VRH might retain mostly eastern white pine while regenerating red pine and other species.

The second pathway is similar to a continuous cover irregular shelterwood [16]. However, when emulating a natural model, it is likely that more trees will be retained to live out their natural lifespans, while also creating spatial patterns of retention that better reflect the outcome of natural disturbance. Moreover, retaining or creating deadwood structures will likely be a bigger focus. Ultimately, providing an opportunity for expression of a preforest stage after a harvest, instead of more immediate site occupancy by regeneration, is another difference in intent from an irregular shelterwood method.

2.3.6 Old Forest Stage

Silviculture in old-stage forests likely will include objectives other than timber production, since old stands are rare on the landscape and may be best managed for ecosystem services other than timber production. Note that mature-stage stands that are managed ecologically will eventually contain old trees and their derivative structures, and these stands may include timber production as an objective, but this is a different situation than management of true old-stage stands.

Silviculture in old stands might focus on restoration of structure and composition, particularly in long-fire excluded stands or those with a history of timber management. Activities might include reducing a dense hardwood and shrub understory and reducing fuels. Prescribed fire or mechanical removal are options to meet these objectives. Enrichment planting or seeding of under-represented species and creation of deadwood might be considered.

If harvesting is pursued at all in old forests it likely will be VDT, used to reduce density and expedite development of structural heterogeneity. In older stands there may be opportunities to place VDT gaps around individuals of species other than red pine. VDT may initiate a preforest stage in gaps as well as establishment of a new cohort of trees. New gaps may need site preparation. Artificial regeneration and competition control in gaps may also be warranted.

2.3.7 Natural-Origin Stands Versus Plantations

There are some distinctions between natural-origin stands and plantations in application of the silvicultural model. Plantations generally will be dominated by healthy red pines of similar size and will lack large deadwood. Thus, leave trees with VRH in plantations may be exclusively red pine, versus multiple species in natural-origin stands. Also, in natural-origin stands there may be several different species to select for deliberate deadwood creation, unlike in plantations.

In the preforest stage, the diversity of native herbs and shrubs may be limited in harvested plantations, while the abundance of invasive shrubs will vary depending on past management history. The potential for mixed-species natural regeneration in harvested plantations will be limited, as seed sources will be lacking, so greater emphasis on planting or direct seeding might be warranted.

Application of thinning in the young- and mature-stage stands may be different in plantations compared to natural-origin stands, primarily because the spatial pattern of trees in natural stands may be heterogenous to some degree already. Also, natural-origin stands are likely to contain tree species other than red pine that can be released or regenerated naturally in VDT gaps. In mature- and old-stage stands, large-diameter dead and decadent trees will be more abundant in natural-origin stands, so deadwood and decadence creation may be less of a need compared to plantations.

2.4 Climate Change Considerations

Managing red pine ecosystems following a natural development model will be challenging with climate change, which in the western Great Lakes region includes increased growing season droughts, but warmer, wetter winters [17]. Many tree species of the ecosystem potentially may face reduced habitat suitability [18], with red pine subject to reduced growth during drought [19]. Still, there are ways to use a natural development model to adapt to climate change, at least in the near to mid-term [1, 20]. Such approaches use a resistance–resilience–transition framework [21, 22].

A resistance strategy in red pine ecosystems includes thinning to maintain tree basal area at levels of low vulnerability, for instance in the range of 14 and 23 m^2 ha^{-1}, compared to ~32 m^2 ha^{-1} used in many timber-focused applications [19]. With this, stand-level growth is better maintained with drought because individual trees have greater access to soil moisture. Also, greater tree vigor may increase resistance to insects and diseases. Moreover, lower basal area is consistent with managing the natural woodland structure of this ecosystem.

A resilience strategy in red pine creates heterogeneity of structure and increases abundance of native future-adapted species. The approach might include a VRH or VDT to create heterogeneity, including gaps and uncut forest, with thinning between these bookends. A resilience strategy will encourage natural regeneration, augmented with artificial regeneration, of native future-adapted species, for example, eastern white pine, northern red oak, and bur oak (*Quercus macrocarpa* Michx.).

A transition strategy presents a challenge for use of the natural model. The strategy likely would reduce red pine abundance substantially over time and increase species that are projected to be better adapted to the developing climate, often using assisted migration. For example, transition may include a VRH in the mature stage and, eventually, regeneration of native species predicted to be climate-adapted (as with resilience), but also species not yet part of the ecosystem in any abundance, for example, white oak (*Quercus alba* L.), bitternut hickory (*Carya cordiformis* (Wangenh.) K. Koch), and black cherry (*Prunus serotina* Ehrh.) [23]. Future entries may expand gaps, thin the matrix, and progressively shift composition to future-adapted species.

2.5 Summary

An ecological silviculture system for red pine ecosystems looks different than a timber-focused model, reflecting closer emulation of the natural development model. Key points to keep in mind that follow from the natural development model include:

1) Retention of structural legacies is the initial aim of regeneration harvesting, with legacies being variable in amount and pattern among stands, reflecting the variable nature of natural disturbance.
2) A VRH initiates a preforest stage, where shrub and herbaceous vegetation dominate, rather than early full site occupancy of regenerating trees. Prescribed fire may be used to initiate the stage.

3) In the young forest stage, when tree regeneration is secured, seedling densities may be lower and their accumulation may be slower than with a timber-focused model, reflecting the woodland structure of these ecosystems.
4) Regeneration of all tree species found in the ecosystem should be encouraged, not just red pine. Activities might include site preparation and competition control, direct seeding, or planting.
5) In the young and mature forest stages, thinning can be used to release trees, create heterogeneity of structure, maintain wildlife trees; this may involve crop-tree release or VDT that includes gaps where regeneration is pursued.
6) Decadence and deadwood creation might be considered in the mature and old forest stages, as these features often are lacking in stands managed using a timber-focused model.
7) Longer intervals between regeneration harvests are likely to be the case when using an ecological silvicultural system, leading to development of structures and conditions that depend on large, old trees. Moreover, regeneration harvests may be less than stand-replacing, resulting in multi-cohort age structures.
8) Variability and heterogeneity – of harvesting, legacies, thinning, decadence creation – is the norm rather than the exception of an ecological silvicultural system, with a goal of promoting native biodiversity, greater habitat diversity, and maintaining options for an uncertain climate future.

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