NATURE CONSERVANCY CANADA

New England–Acadian Forest Restoration

A Landowner's Guide to Theory and Practice

By Josh Noseworthy

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"One of the penalties of an ecological education is that one lives alone in a world of wounds. Much of the damage inflicted on land is quite invisible to laymen. An ecologist must either harden his shell and make believe that the consequences of science are none of his business, or he must be the doctor who sees the marks of death in a community that believes itself well, and does not want to be told otherwise."

-Aldo Leopold

This book is dedicated to those who
wish to see the community well once again.

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Josh Noseworthy

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Introduction

If you picked up this manual out of interest, you're likely already aware of the economic and ecological importance of the New England–Acadian Forest. You may also know that the New England–Acadian Forest has been deemed an endangered forest ecosystem.[1] Over the past four centuries, the effects of logging and land conversion have created a forest landscape that is fundamentally different from what existed previously.[2] Many of the practices that changed the face of the land continue into the present day, and on a much larger scale and with greater intensity. Although forestry and agriculture are essential to a healthy economy, an ever-growing body of evidence suggests that the scale and intensity of both past land clearing and present forest management create challenges for conserving New England–Acadian Forest biodiversity. Corroboration continues to build as we witness declines in forest communities,[3] species,[4] and genetic diversity across the region.[5] Forests composed of long-lived, shade-tolerant, late-successional tree species are declining, and these declines raise questions about our ability to maintain regional forest biodiversity in the long term.[6] If as a society we truly want to take sustainability seriously, we must consider biodiversity in its fullest.[7]

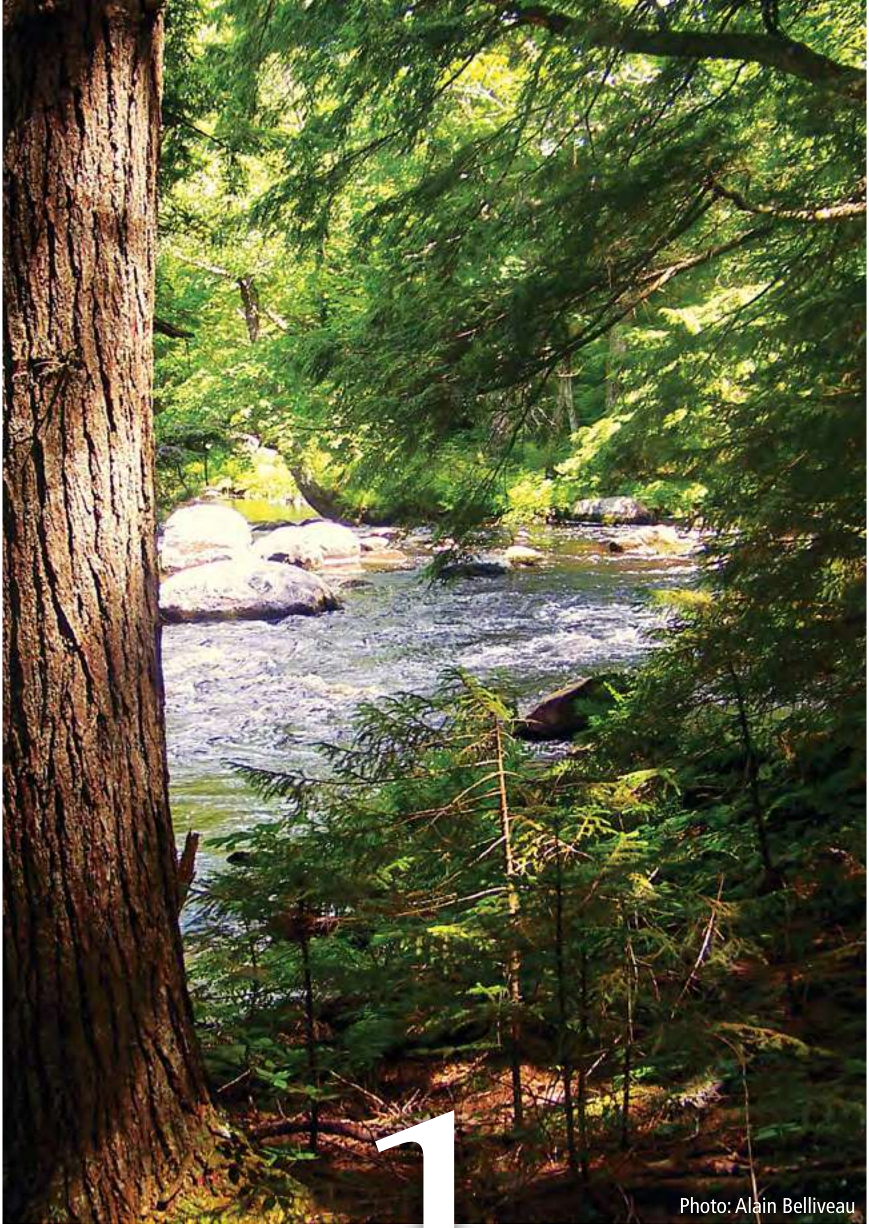
Those who wish to see healthy New England–Acadian Forest can contribute to its restoration using the same forestry practices that have contributed to its decline. As forester and conservationist Aldo Leopold wrote in a 1933 textbook on wildlife management, "The central thesis of [wildlife] management is this: [wildlife] can be restored by the creative use of the same tools which have heretofore destroyed it."[8]

Restoration of the New England–Acadian Forest, with all the species and communities that contribute to our natural heritage, requires using silviculture in creative ways to promote biodiversity. This is not a new concept. The scientific literature is full of calls for the sustainable management and restoration of late-successional forest, and individuals and organizations across the region are managing woodlots for a variety of values, including wildlife and biodiversity. Many authors have described best management practices and stewardship concepts for sustainable forest management, often specifically for this region. However, technical guidance on restoring New England–Acadian Forest communities on degraded and converted lands is scarce. The purpose of this manual is to provide woodlot owners, land trusts, and protected area managers with that technical assistance.

Although landowners might manage their woodlots for a variety of values, this manual focuses only on management for biodiversity conservation over the long term. Yet in no way should it be considered at odds with commodity-based woodlot management. Silviculture costs both time and money, and in many cases, objectives cannot be met without some cost recovery. However,

since commodity-based management is the norm, traditional silviculture prescriptions are often presented only if economically practical, or at least cost neutral, which often result in conservation values being sacrificed for economic ones. For some forest managers, however, biodiversity conservation is the primary management goal, and when economic constraints (real or perceived) are removed or relaxed, several useful tools become available.

If you are among those forest managers and woodlot owners who wish to promote native biodiversity in the New England–Acadian Forest region, this manual was written for you. To use the prescriptions in this book, no prior forestry experience is needed, only some basic understanding of woodlot management and tree identification. Chapter 1 introduces the New England–Acadian Forest and highlights the concepts surrounding its restoration. Chapter 2 reviews the silviculture treatments that are referenced throughout the remainder of the manual; it provides all the technical information needed to implement the concepts introduced in Chapter 1. Chapters 3–8 describe the scenarios you may find on your land and lists their appropriate restoration treatments. Finally, Chapter 9 offers ideas and recommendations for promoting and hastening restoration in the New England–Acadian Forest region.



1 CHAPTER Forest Restoration Goals

For the purposes of this manual, the New England–Acadian Forest combines two terrestrial ecoregions as defined by the World Wildlife Fund[1]: the New England–Acadian Forest[2] and the Gulf of St. Lawrence Lowlands.[3] On the Canadian side, these two ecoregions span the three Maritime provinces (minus the highlands of New Brunswick and Nova Scotia) and a portion of southeastern Quebec. The U.S. side covers most of New England, excluding the southern coastal plain, and includes a small portion of eastern New York (Figure 1). Historically, this region was dominated by late-successional forest composed of tree species adapted to regenerate under partial shade.[4] When old trees died, leaving gaps in the canopy, younger trees took advantage of the available light and grew to fill in the openings. Gap replacement, repeated over millennia,[5] is a natural disturbance dynamic that favours the long-lived, shade-tolerant, and late-successional forest communities that once dominated the landscape.[6] In contrast, natural dynamics in boreal systems involve larger-scale disturbances, such as fires, windstorms, and insect infestations. Boreal tree species have adapted to these dynamics and can easily regenerate in open, exposed conditions.[7] Although boreal species have always been a component of the overall biodiversity of the region, they were generally restricted to localized conditions, such as boggy ground, high elevations, and exposed coastal areas.[8]

Figure 1. Geographic extent of the New England-Acadian Forest region.

Borealization refers to the landscape-scale replacement of long-lived, temperate forest communities by early-successional ones, similar to those of the boreal forest. In the New England–Acadian Forest region, the exposed conditions created by clearcutting, high-grading (the removal of the most commercially valuable trees), and farmland abandonment have collectively contributed to a superabundance of these short-lived, early-successional forest communities. In some cases, this turnover was purposeful, such as the past practice of clearing tolerant hardwoods to establish conifer plantations. In other cases, borealization was an unintended result, such as the historic conversion of bottomland forests to agriculture and the subsequent regrowth of early-successional species after abandonment. Collectively, land clearing and conversion have degraded all but a few remnant patches of unaltered forest across the region.[9] However, not only is borealization preventable, it is also reversible. With the creative use of silviculture and a little patience, healthy New England–Acadian Forest communities can be restored, along with the diverse array of wildlife that depend on them. As landowners and managers restore these forest communities, native wildlife will benefit both at the individual property level and also, we hope, at the landscape scale. The ultimate vision for the region is to have a network of large, connected tracts of healthy, late-successional forest that supports the full suite of native biodiversity.

Forest restoration is a long-term process, requiring foresight and patience on a scale unlike any other form of forest management. It can take centuries for a forest to reach a late-successional state of self-renewal. When undertaking a restoration project, we must understand that the fruits of our labour may not be witnessed in our lifetime. Restoration requires a strong land ethic[10] and a commitment to the long-term health of the forest. Whatever your motivation—concern for the legacy left to future generations, a mandate to conserve wildlife, or just a general desire to see how management techniques can improve your woodlot—restoring New England–Acadian Forest on your land will require commitment.

So what exactly does it mean to manage for biodiversity? When we speak of biodiversity in general, we are talking about the total sum of genes, species, and ecosystems that naturally exist in a given region. This manual focuses on late-successional forest biodiversity because even though young and early-successional forests are also important for many wildlife species, they are highly abundant across the region and do not require interventions for their conservation.[11]

Managing for biodiversity does not mean managing only for the plants and animals that we happen to enjoy or that are obvious to us. It means managing for unseen, overlooked, and cryptic species as well: the lichens, beetles, soil microbes, mosses, fungi, rodents, reptiles and amphibians, and all the other forms of life that contribute to healthy forest ecosystems. Of course, it would

be impractical to manage for each of these on an individual basis, and even if we could, we do not currently know the total sum of diversity that exists in the region, as new species are still being discovered.[12] However, we do have a good idea of the conditions that this diversity depends on, and by managing for this set of forest conditions, we can promote and conserve a wide array of forest biodiversity. To do so, restoration aims to accomplish three primary goals, each of which is detailed below.

Restoring Tree Species Composition

When we discuss tree species compositions, we are actually talking about forest communities. Trees are not spread out in a random fashion. Depending on soils, topography, and local climate, species form discrete groups that are repeated across the landscape wherever their particular growing conditions are met.[13] This allows for classification of forest communities. Throughout this manual, we refer to the Forest Ecosystem Classification for Nova Scotia,[14] and the Natural Landscapes of Maine.[15] Together, these classifications address most of the forest communities found across the New England–Acadian Forest region, and descriptions of each community are freely available online.[16]

When deciding what forest communities to restore, we often lack detailed information on the species compositions that occurred prior to land conversion or degradation. However, using tools that assist in making the decision process easier will also increase the chances of a successful restoration project. The most useful tool is a reference community,[17] which allows for comparison between the restoration site and a nearby forest community that supports the late-successional conditions we are aiming to restore. Ideally, the reference community is an unharvested woodlot or a protected area that is adjacent to

Photo: Alain Belliveau

the restoration site, but this situation will not exist throughout most of the region. If available, historical aerial photography can shed light on the forest communities that once occurred on your land. You can also look for individual large, old trees, which can provide insight into the type of forest that once grew on the property; boundary lines are a good starting point for locating these trees. In the complete absence of information, mapping the specific site conditions across the land will allow you to choose species that are best suited to those conditions, as discussed in Chapter 2. Throughout this manual, species of trees, shrubs, and other plants are referenced using their common names. For the corresponding scientific names, refer to Appendix E.

Species Selection

When restoring a tract of land, certain tree species should be favoured over others. Table 1 provides general selection recommendations for the tending and harvesting prescriptions used throughout this manual. The criteria for these selections were the general rarity and range restrictions of tree species native to the region,[18] their affinity toward temperate or boreal conditions,[19] their historical contribution to old-growth,[20] and their genetic conservation requirements.[21] In general, the preferred trees are long-lived, shade-tolerant, temperate species, particularly those that are becoming rare or uncommon. Columns 1–3 represent this group of species, with those in column 1 being the most desirable. The selection recommendations tend to favour tolerant softwood and mixedwood communities and, where temperate conifers are absent, tolerant hardwood communities. Temperate conifers are favoured because of their long history of selective removal from hardwood and mixedwood stands[22] and their restricted ability to recolonize an area once removed.

Table 1. Tree species selection priorities for New England–Acadian Forest restoration

Most desirable				Least desirable
1	2	3	4	5
Ironwood	Red Spruce	White Ash	Red Maple	White Spruce
White Elm	Eastern Hemlock	Yellow Birch	Black Spruce	Tamarack
Black Ash	Eastern White Cedar	Sugar Maple	Jack Pine	Balsam Fir
Beech (clean*)	Red Oak	Black Cherry	Large-Tooth Aspen	Beech (diseased*)
Red Pine	Eastern White Pine		Balsam Poplar	Trembling Aspen
				White Birch

*See Appendix A for Beech management.

Although Table 1 provides general selection priorities for the restoration of the most common forest communities, in some situations exceptions must be considered, as in the following cases:

Unique forest communities. Table 1 covers only the major species in the region because some tree species do not occur in all areas of the New England–Acadian Forest. These species either have a restricted range or require specialized habitats with limited distribution. Species such as Pitch Pine, Basswood, Butternut, Bur Oak, Red Ash, and Silver Maple are generally uncommon and should be maintained and encouraged wherever they are naturally found. See Chapter 8 for more information on unique forest communities and their restoration. Additionally, certain tree species with southern affinities may occur along the southern border of the region, or as disjunct populations within it. Generally, these species are rare or uncommon and should also be conserved and encouraged wherever they are found. For a list of these tree species and their habitat preferences, see Appendix F.

Shrubs and small trees. Small trees and woody shrubs—Striped Maple, Mountain Ash, Witch Hazel, willows, and serviceberries, among others[23] —are equally important to the overall diversity of the New England–Acadian Forest. However, it is beyond the scope of this manual to address their restoration. As a rule, shrub diversity should be maintained and restored wherever possible, particularly those species that are rare or uncommon in your area.

Choosing between desirable species. You may occasionally have to decide between two species in the same column of Table 1. If so, favour the species that is less abundant in your area. Similarly, if selecting a species from a lower-ranked column would increase the overall diversity because it is uncommon (e.g., scattered Yellow Birch in a Red Spruce stand), favour the less abundant species.

In all cases, the general principle for deciding what trees to promote and what to remove is simple: <u>When in doubt, err on the side of diversity</u>.

Excluded Situations

Although this manual provides guidance on a range of possible scenarios, in some situations the prescriptions do not apply.

Nonnative species. Because they are not part of the biodiversity goals that this manual sets out to achieve, exotic species are collectively treated as a threat to New England–Acadian Forest biodiversity. Nevertheless, in some cases, nonnative species may need to be retained for a time. For example, conifer plantations are often composed of nonnative species that may need to be managed as a nurse crop (trees or shrubs whose presence improves the survival rate of young trees) as the stand transitions into a late-successional community. However, the end goal should be the complete removal of all nonnative species.

Invasive species. The health of the forest in your area may also be threatened by invasives. It is beyond the scope of this manual to address the various ways of managing invasive species, but because Norway Maple, Japanese Larch, Scots Pine, Glossy Buckthorn, and other exotic trees, shrubs, and herbaceous species have the ability to invade forested areas, they should be eradicated.[24]

Natural boreal communities. Several boreal forest community types naturally occur across the region, and the management prescriptions in this manual do not apply to them. Coniferous forest wetlands[25] of Black Spruce, alone or with pine or Tamarack, are exempt. These are the natural communities that colonize on poor, wet soils and tend to be compositionally homogeneous (see Chapter 8 for forested wetland restoration). Forests in highlands also tend to be boreal by nature[26] and are also exempt. Coastal forest communities[27] in exposed areas have a natural boreal affinity and are generally exempt, with the exception of those that show evidence of supporting Red Spruce or other late-successional species[28] (see Chapter 8 for coastal forest restoration).

Restoring Older Age Classes

Borealization has not only changed the composition of tree species across the landscape, it has also drastically changed the average age of the forest. Today, forests throughout northeastern North America are dominated by small-diameter stems that rarely exceed 60 years before being cut.[29] In contrast, undisturbed New England–Acadian Forest communities can easily reach 200 years or more,[30] and in many cases, individual trees can reach 400 to 500 years old.[31] Historically, these old forests covered upwards of 85% or more of the forested landscape before European settlement.[32] Today, these forests cover only 5% on the U.S. side of the region, and less than 1% on the Canadian side.[33]

Photo: Alain Belliveau

In addition to allowing desirable tree species to age naturally, we can also influence development toward older forest conditions. The relationship between age and forest development is not perfect; ages are only approximations of development stage. However, the conditions we want to encourage to promote forest biodiversity are directly associated with older forests. Although technical definitions of age classes and development stages differ between regions and forest communities,[34] for the purposes of this manual, a general relationship is defined in Figure 2. The silviculture prescriptions presented throughout this manual will apply to these forest development stages, rather than age.

Development Stage

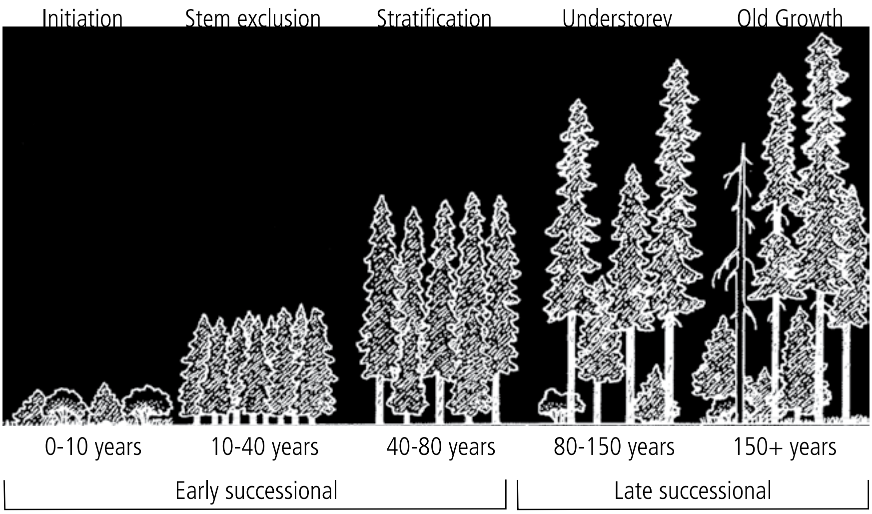


Figure 2. Generalized forest development stage and age class definitions for New England–Acadian Forest restoration. Adapted from Thomas[35] and Oliver[36], and published with permission from the USDA Forest Service, 2017.

Initiation

Stand initiation typically follows a large disturbance such as clearcut harvesting or farmland abandonment. Numerous early-successional plants begin to colonize, and forbs and graminoids rapidly yield to woody shrubs, then to early-successional trees. This process continues until trees occupy all available growing space.

Exclusion

The exclusion phase begins when new trees are unable to colonize the area because all available growing space is filled. Trees begin to compete with one an-other for sunlight, water, and soil nutrients and typically form a dense thicket. The exclusion stage features a single canopy layer, which gives it a "brushy" appearance.

Stratification

Stratification occurs once competition between trees begins creating differentiated canopy layers. Many trees weaken or die because of the intense competition; others grow taller, overtopping the suppressed trees and gaining canopy dominance.

Understorey

The understorey stage begins when the stratified canopy layers become fully expressed, and growing space becomes available because of tree mortality due to competition. Trees and other plants begin to regenerate in the understorey, forming a new canopy layer. Many of the understorey trees remain in a suppressed state because little light reaches the forest floor.

Old-Growth

When mature trees die, the gaps left in the canopy admit light to the forest floor. The understorey begins to grow and stratify into a new set of canopy layers. Dead trees also create structure in the form of snags and large downed logs. Although there is no consensus on the definition of old-growth, it is generally accepted that 150-plus years is needed to establish old-growth conditions in the region.[37] Silviculture cannot make the forest age any faster, but it can be used to speed up the development process by creating the conditions that old-growth forests provide, and doing so at a quicker rate than without management—by favouring desirable tree species, accelerating the growth of certain trees, and creating canopy openings for new trees to establish. Once old-growth forest conditions are achieved and self-perpetuating, the forest will no longer require management.

Restoring Structural Diversity

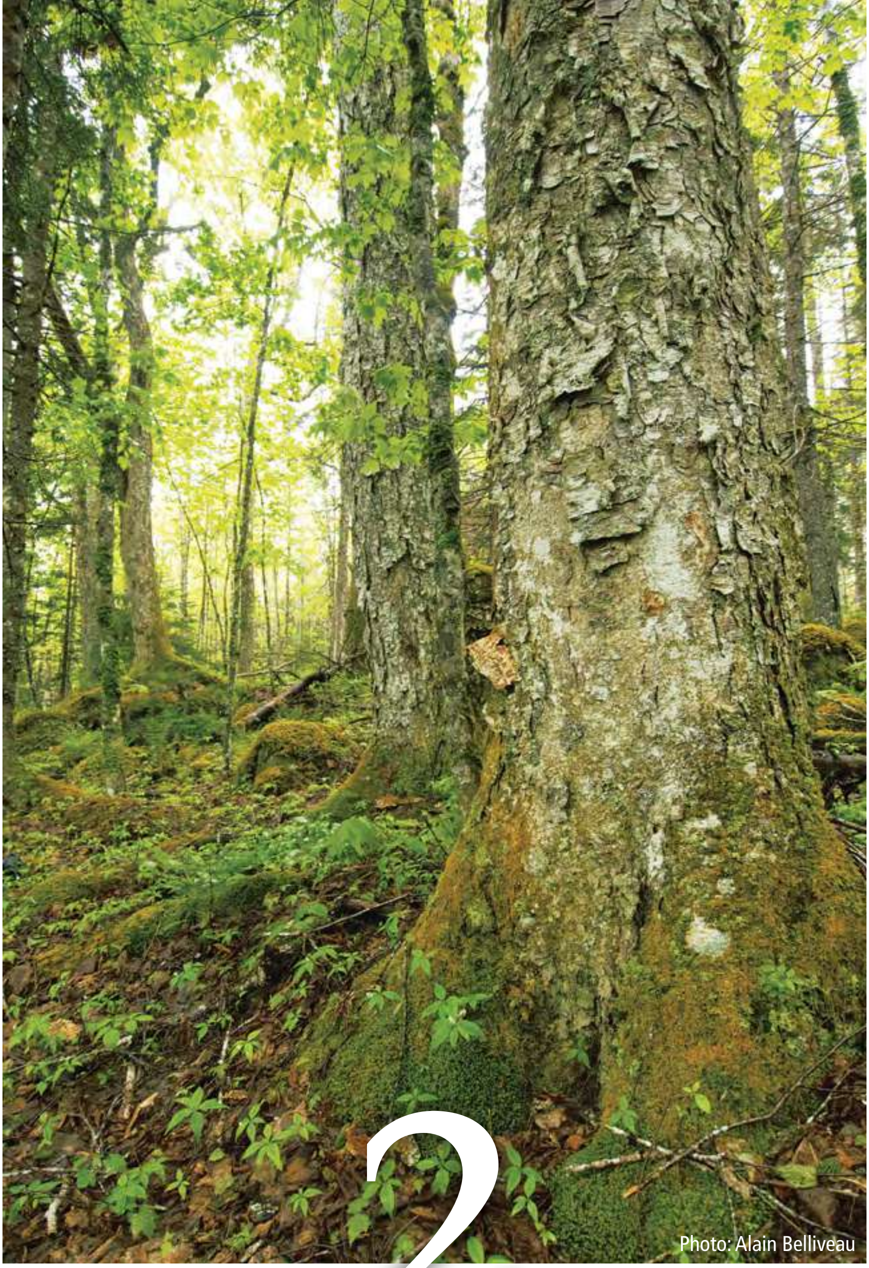
Restoring structural diversity is directly tied to promoting the conditions of late-successional forest.[38] The structure of a mature forest has many aspects, and when fully accounted for, they are a strong indicator of the overall biodiversity in forests.[39] The structural complexity that develops as a forest matures creates diverse microhabitats, which subsequently increase the number of organisms that can persist in the forest.[40] Forest structure can be grouped into two main categories: living and dead. Living structure refers to the variety of canopy levels in the forest, from the towering White Pine[41] to the shrubs and suppressed seedlings in the understorey. As a general restoration rule, forests

with a variety of canopy layers will support a greater number of species than forests with a single, even-aged canopy.[42] To achieve this kind of structure, restoration aims to promote a variety of shade-tolerant tree species, ages, and canopy levels.

Deadwood structure is also an essential part of maintaining wildlife in forests. Dead branches, snags, stumps, and decaying logs provide critical habitat for an incredible variety of life.[43] Although cavity-nesting species are the most obvious to benefit from deadwood, the decay process involves many less noticeable species. For example, the number of known beetle species that live on dead and dying wood is twice the number of all mammal, bird, reptile, and amphibian species combined.[44] Decaying deadwood is also ecologically important because it holds moisture in dry periods, slowly releases nutrients back into the soil, and acts as a nursery bed for many trees and other plant species (called nurse logs).[45] Additionally, as trees fall down, they may create topographic diversity across the forest floor. This pit-and-mound topography has its own set of important ecological roles.[46]

The silvicultural guidelines in this manual promote structural diversity both directly and indirectly through the creation of snags and downed logs, by leaving legacy trees, and by favouring the long-lived, shade-tolerant tree species that will develop stratified canopies over time. Although management cannot replace the entire suite of structures that a natural old-growth forest contains, we can provide these measures in the interim, while the forest naturally matures over time.


Photo: Alain Belliveau



2
CHAPTER
Silviculture Prescriptions

This chapter describes the silvicultural prescriptions that will be used throughout the remainder of the manual. Many of the treatments are taken directly from *Silviculture Concepts and Applications*, by Ralph Nyland,[1] although a few reflect the "creative use" of these traditional treatments. Since the purpose of restoration is to influence forest conditions rather than to extract a product, treatment qualifiers such as "commercial" or "pre-commercial" become irrelevant. Instead, prescriptions for each restoration scenario are organized by the forest development stage that they are intended to influence. The treatments described are not meant to encompass the entire suite of options that can be used to restore forests; rather, for simplicity, the list captures those treatments that can be implemented by small woodlot owners and industrial foresters alike. Prescriptions were selected, where possible, for their ease of implementation, their success in restoring forests in other regions, and their resemblance to the natural gap-disturbance dynamics that the New England–Acadian Forest depends on.

Implementing silviculture treatments of any kind will affect the land, and any negative impacts on biodiversity should be minimized. *Restoring the Acadian Forest*, by Jamie Simpson[2], offers a wealth of information on harvesting guidelines, best management practices, and ethical land stewardship concepts that do not need to be repeated here. His book should be used in combination with the prescriptions in this manual.

Prescriptions are organized into five categories: site preparation, planting, tending, regenerating, and structural additions. Each prescription is defined and accompanied by information on how to implement it and what it aims to achieve.

Site Preparation

Proper site preparation is the most important aspect of establishing a forest on previously cleared land. The following list is restricted to mechanical site preparation techniques and does not include the use of chemical herbicides. Chemical treatments were purposefully left out of this manual because some jurisdictions in the region do not allow the private use of herbicides. Moreover, a growing body of evidence suggests that commonly used herbicides have the potential to harm both wildlife and human health.[3] Research also shows that with care, mechanical site preparation alone can achieve the desired restoration outcomes.[4]

Mowing, Bush Hogging, and Mulching

Mowing and bush hogging are the most basic forms of site preparation. They can be used alone, such as when sensitive soils cannot be disturbed, or in preparation for more aggressive techniques. Mowing and bush hogging can involve a variety of tools, from hand-held string trimmers to tractor attachments, depending on the scale of the project. Since the purpose of mowing is to clear undesirable vegetation, the intensity of mowing or bush hogging also depends on the vegetation to be cleared. When mowing is the only form of site preparation to be used, mowing in summer and fall will have the greatest effect on undesirable vegetation. Mowing is also an important aspect of maintaining the site after planting. Whether mowing is used alone or in combination with other site preparation treatments, you should plan to follow a mowing schedule for at least three years after planting.[5] This will discourage vegetation that competes with planted trees, and also deter rodents that nest in dense vegetation and girdle young trees. Additionally, applying bark mulch in a 15–25cm (6–12-inch) radius around planted trees is an excellent way to suppress herbaceous field vegetation and can lessen the amount of mowing required.[6]

Plowing and Disking

Plowing and disking are the ideal techniques for preparing old farmland for tree planting, and they are essential unless soils are too sensitive to allow for machinery.[7] The method prepares the site for tree planting by (a) aerating the soil, (b) destroying competing vegetation, including deep-rooted perennials, (c) allowing water to penetrate the soil, and (d) stimulating beneficial soil microbes.[8] Plowing and disking require the use of machinery to aggressively disturb compacted soils and are therefore not recommended in boggy or rocky soils, or soils sensitive to erosion. First, a plow digs under the compacted sod layer and overturns it; a disk harrow then cuts, loosens, and mixes the overturned sod and soil. Plowing and disking should occur at a minimum depth of 15cm (6 inches), but the goal is to disturb the entire compacted soil layer. On highly compacted soils, depths up to 60cm (2 feet) can be plowed and disked.[9] Heavily compacted soils may need to be plowed and disked multiple times. If soils are wet or subject to spring flooding, plow and disk in autumn to facilitate a spring planting the following year. On well-drained soils, plowing and disking can be done directly before planting, or up to several months beforehand if a mowing schedule is maintained.

Cover Cropping

Although not specified as a prescription in subsequent chapters, cover cropping is a viable way of improving soil fertility, decreasing erosion, and controlling competing vegetation on abandoned farmland.[10] If fields are depleted of nutrients, or if planting cannot occur in the same year as site preparation, sowing a cover crop after plowing and disking can significantly increase the success rate of a restoration project. Commercial cover crops are used for agricultural purposes, and although very little information is available about their use for restoring forests on abandoned farmland, Red Clover,[11] Sweet Clover,[12] or Alfalfa[13] may provide the greatest benefit; all three increase soil nitrogen, build soil organic matter, and quickly break down after being tilled under before tree planting. If plowing and disking occur in autumn, an alternative cover crop is Winter Rye.[14] Establishing alder may be a longer-term option on nutrient-depleted lands. Alders are excellent at building soil organic matter and replenishing nitrogen, and can grow in a wide range of soils. See Appendix B for more information on establishing alder.

Tilling

Tilling is intended to prepare a planting bed and control competing vegetation in soils that are not compacted. A tiller uses rotating tines to break up the soil and mix in surface organic matter. For restoration, tilling can be used to break up a cover crop on agricultural land before planting trees, or to prepare openings in a forest dominated by undesirable herbaceous vegetation. Tilling options depend on the size of the area. For large restoration projects, such as tilling under cover crops on old farmland, heavy equipment may be required. In areas that are relatively small, a rear-tine rototiller can be used to prepare a planting site, and a hand tiller may suffice to prepare small planting beds within forest openings. Regardless of the method, tilling should extend to a minimum depth of 15cm (6 inches) to destroy undesirable vegetation. Like plowing and disking, tilling can be done in autumn to facilitate spring planting on wet or seasonally flooded soils, or directly prior to planting on well-drained soils. If tilling is used to create a seedbed for natural regeneration, till in late summer to coincide with seed dispersal for most desirable tree species.

Planting

Planting is considered a last resort when restoring forests. Natural regeneration should be favoured wherever it occurs, and if the seed source is available, using silviculture to promote natural regeneration can save both time and money. However, when planting is required, as it often will be when restoring degraded lands, there are several factors to consider.

Species

Matching species to the right site conditions will provide the greatest restoration success. As mentioned in Chapter 1, using a nearby reference community is the best way to choose which species to plant. In the absence of this, legacy trees may be useful. If no information is available, select planting mixes based on the soil moisture and nutrient requirements of common upland New England–Acadian tree species (Table 2).[15] For species used to restore forested wetlands, floodplain forests, and other unique communities, see Chapter 8.

Although the final planting mix will likely reflect the nursery stock that happens to be available at the time, the main goal is to plant a diversity of species that are suited to the site conditions on your land. To learn how to assess your land according to the categories in Table 2, see Appendix C.

Table 2. Planting mixes of New England–Acadian tree species, by soil moisture and nutrient requirements

Moisture Requirements	Nutrient Requirements: Poor	Nutrient Requirements: Medium	Nutrient Requirements: Rich
Moist	Eastern White Pine Red Oak	Eastern White Cedar Eastern Hemlock Red Spruce Yellow Birch Red Oak	Eastern White Cedar Sugar Maple Yellow Birch White Ash Red Spruce Eastern Hemlock
Fresh	Eastern White Pine Red Oak	Eastern White Pine Eastern Hemlock Red Spruce Yellow Birch Sugar Maple Beech Red Oak	Eastern White Cedar Sugar Maple Beech Yellow Birch White Ash
Dry	Eastern White Pine Red Oak Red Pine	Eastern White Pine Eastern Hemlock Red Spruce Red Pine Beech Red Oak	

Genetics

Genes are the basic unit of biodiversity, and maintaining the genetic diversity of native species is therefore essential for successful forest conservation and restoration.[16] For small projects, this can be accomplished simply by digging up native seedlings in your local watershed (with the landowner's permission). However, for large projects, obtain trees from nurseries that can provide genetic stock that is both native and adapted to your specific area. This will not only benefit gene conservation but can also increase the survival rate of the planted trees.

Planting Stock

Choosing trees of good quality and of the appropriate size can make the difference between success and a failed restoration project. Generally, planting stock taller than 30cm (1 foot) with sturdy stems and well-developed root systems is desirable.[17] Bareroot stock more than 1m (3 feet) high with well-developed root systems will provide the highest rate of survival and growth response[18] but may be too costly or not available in sufficient quantity for large-scale restoration projects. Seedling plugs may be a more viable option in these cases. The survival rate of seedling plugs is considerably less than that of large, sturdy planting stock, but failed seedlings tend to be easier and cheaper to replace. Seedling plugs are much more susceptible to competition with herbaceous vegetation, and they are not recommended for planting on abandoned farmland unless aggressive site preparation and vegetation control have been used. If you are planting on sites that can only be prepared by mowing, large planting stock—more than 1m (3 feet) in height—will be required.

Spacing

Generally, trees should be closely spaced so that canopy closure occurs as quickly as possible. In open settings, such as abandoned farmland, this will help discourage competing vegetation as well as promote upward growth rather than branchy, poorly formed stems.[19] For planting in open areas, a spacing of 2m by 2m, or 2,500 trees per hectare (6 feet by 6 feet, or ~1,000 trees per acre) is recommended for all tree species. However, if machinery will be needed to control competing vegetation, spacing of 3m by 1.5m, or ~2,200 trees per hectare (10 feet by 5 feet, or ~900 trees per acre) can facilitate mechanical weeding. As a rule, planting in irregular or crooked rows is considered a best practice for restoration because it more closely resembles natural forest succession, but straight rows may be necessary for machinery. If you are planting beneath an existing forest canopy (i.e., fill planting or underplanting), shade from adjacent trees will already be present, and a spacing of 3m by 3m, or ~1,100 trees per hectare (10 feet by 10 feet, or ~450 trees per acre) can be used instead.

Protection

In many cases, planted trees require protection from herbivores, typically deer and hare. Including protection is an additional cost, and for some projects, it may be more feasible to accept a certain level of loss than to invest in tree protection. Before investing in seedling protection, assess the determining factors, such as the scale of the project, the density of herbivores in your area, and your ability to discourage herbivores in other ways. Tree protection strategies range from do-it-yourself chicken-wire mesh to commercial polyethylene tree shelters. If cost is not prohibitive, consider commercial tree shelters, which have been shown to be highly effective against herbivores[20], as well as against herbaceous vegetation on old fields.[21] Although the height of tree shelters depends on the herbivores being protected against, tree shelters that are 1.5m (5 feet) tall generally work well against all potential herbivores.[22]

Treatments

Whether you plant seedling plugs, container stock, or bare-root stock, plant carefully and ensure that the planting style matches the stock. Planting in holes that are too small or too shallow may result in root-bound trees that will not survive. Conversely, holes that are too large or deep can create air pockets that will kill expanding root systems. For more information on good planting methods, refer to *Planting Hardwood Seedlings in the Central Hardwood Region*, a USDA manual.[23] Four kinds of planting treatments are suggested for restoration:

Fill planting. Trees are planted in canopy openings in an already-forested area. Fill planting is generally restricted to dense conifer forests where little light reaches the forest floor. In these conditions, patches can be cut to permit sunlight, and trees are then planted to fill the patch.

Underplanting. Trees are planted directly under the existing forest canopy in an already-forested area. Underplanting is generally restricted to hardwood forests, where dappled light conditions already exist.

Blanket planting. The restoration site is fully planted with trees in a uniform spacing of 2m (6 feet) square. It is used for restoring open areas, such as abandoned fields. Although blanket planting is the more costly and labour intensive of the two open-area planting treatments, it promotes a closed canopy sooner than the next alternative, island planting.

Island planting. Trees are planted in groups scattered throughout the restoration site. Like blanket planting, island planting is used in open areas, such as abandoned fields. Commonly applied in tropical forest restoration,[24] it may be the preferred option when seedlings are not available in quantity or are too costly. The islands should be circular and at least $100m^2$ or approximately 11m in diameter (120 square yards or 36 feet in diameter),[25] although patches $300m^2$, or approximately 20m in diameter (328 square yards or 65 feet in diameter), or larger are recommended. Trees within each island can be planted at a spacing of 2m by 2m (6 by 6 feet). The island areas can be expanded outward over time. Although no defined number of islands per unit area is suggested, the general rule is to plant as many large islands as possible, evenly spread across the restoration site, with the aim of connecting them over time.

Tending

Tending refers to a variety of treatments that are implemented in established forests. The aim of tending for restoration is to (1) favour desirable tree species, (2) free selected trees from competition, (3) increase the growth rate of desirable trees, (4) promote good form, and (5) create structural complexity.

Weeding

Weeding is done during the initiation stage of forest development. Competing herbaceous or shrub vegetation is removed within a 1m (3-foot) radius around desirable young trees. Depending on the scale of the project and the intensity of competition, weeding can be implemented manually or mechanically, such as through mowing and trimming. Weeding may be required multiple times until desirable trees have outgrown the competition.

Cleaning

Cleaning is implemented in the initiation and stem exclusion stages of forest development. The aim is to remove overtopping stems that are suppressing desirable tree species. This is a common scenario after clearcutting, when early-successional hardwoods may overtop slower-growing desirable species. Cleaning a stand ensures that desirable species are favoured and will become part of the dominant canopy layer as the forest matures. If no desirable species are being overtopped, undesirable species can be left alone to encourage full use of the growing space. There is no spacing requirement during cleaning; the focus is simply to remove overtopping species that are undesirable. Cleaning can be implemented manually or mechanically, depending on the scale of the project and the degree of overtopping.

Culling

Culling can be implemented in any stage of development; however, it is most often applied in earlier development stages to give desirable species a competitive advantage. Culling is defined as the removal of all trees that meet specific criteria, which is often species-based. There is no spacing requirement when culling, since the treatment simply focuses on lowering the composition of undesirable trees.

Crop-Tree Release

Crop-tree release can be implemented at any point as a stand develops but is most frequently prescribed in the stem exclusion and stratification stages. The release is applied using the crown-touch method; adjacent trees that touch the crowns of crop trees are removed, but canopy closure is maintained by leaving the remainder of the stand untouched. If two crop trees are adjacent to each other, both can remain as long as three-quarters of the crown of each is free of competition. There is no spacing requirement with this treatment; the intent is simply to remove competition around all trees that meet the crop tree definition. However, a general rule is to select more crop trees—100 to 200 trees per hectare (40 to 80 trees per acre)—in younger development stages and fewer in older development stages, where 50 to 100 trees per hectare (20 to 40 trees per acre) will suffice.[26]

Crop-Tree Release with Spacing

This treatment is similar to a crop-tree release but includes a spacing requirement for the remainder of the stand not containing crop trees. It is restricted to the exclusion and stratification development stages. Crop-tree release with spacing aims to favour desirable tree species while increasing the growth of residual stems that do not meet the crop-tree definition.[27] Since the density of crop trees will be variable, the final stand density will also be variable, but spacing among non–crop trees should not fall below 1,700 stems per hectare, or 2.4m-by-2.4m spacing (~690 stems per acre, or 8-by-8-foot spacing).[28]

Release Cutting

Release cutting is implemented in the understorey development stage. This treatment releases young desirable regeneration from an overstorey nurse crop, once regeneration has reached an average height of 1m (3 feet). Overstorey trees should be removed periodically, wherever regeneration meets the minimum height requirement. This periodic partial release reduces crowding of overstorey trees while maintaining a canopy that provides dappled light. Generally, three or more overstorey trees per hectare (1 or more overstorey trees per acre) should be set aside as legacy trees to provide stand structure and wildlife habitat (see Structural Additions, below).

Pruning

Trees are pruned in the initiation and exclusion development stages only. For restoration purposes, pruning is prescribed only for trees that are grown in an open setting, such as those that colonize or are planted on abandoned farmland or in a high-graded stand. Conifers growing in the open are often described as "cabbage" trees; they tend to be bushy and have poor vertical growth because of forking from damaged central leaders. Without pruning, these trees often become suppressed and die. For young, open-grown conifers, prune back all but a single dominant leader to avoid "cabbage" growth. On trees that have already "cabbaged," prune all but a single dominant leader, as well as the bottom half of the live crown. If possible, prune branches before they reach 5cm (2 inches) in diameter.[29] For hardwoods planted in old fields, strategic pruning can greatly improve upward growth and form, although the recommended dense spacing of 2m by 2m (6 by 6 feet) should generally limit branching and forking. As with conifers, the main goal of pruning is to remove multiple leaders, favouring one that is healthy and dominant. If trees begin to produce branches at the base of the stem, prune the lowest branches in the third year after planting, and every two to three years afterward until canopy closure is achieved.[30] This will promote upward rather than outward growth. For all trees, pruning is best done in late autumn or winter, when trees are dormant, and only after the third growing season to give trees adequate time to establish a healthy root system so that they can quickly recover. Never prune more than two-thirds of the live crown of a tree. For details on proper pruning techniques, refer to the USDA guide *How to Prune Trees*[31]. Once trees reach the stratification stage, they should no longer be pruned. Branching and forking in later stages of development can create wildlife habitat that should be encouraged.

Regenerating: Patch Cutting

Regenerating treatments promote conditions for seedling establishment, either naturally or through planting. The aim of regenerating treatments is to (1) create canopy openings for desirable regeneration, and (2) begin developing multiple canopy layers. For restoration purposes, a single treatment is suggested across the various restoration scenarios—patch cutting.

Patch cutting to establish regeneration, either natural or planted, can be used in all development stages except initiation. Patches are intended to mimic the natural gap-disturbance dynamics of the New England–Acadian Forest. Patch cutting design is area-based rather than volume-based or otherwise, and is determined using three principles:

1. Patches that are approximately 300m^2 (328 square yards) have been shown to be best for establishing regeneration of New England–Acadian species.[32] The patch size is directly related to average stand height, since regeneration requires partial shade from the surrounding forest. To determine patch size, use the following rule of thumb:
   - If average tree height is 20m (65 feet) or greater, then the patch is 20m in diameter, or about 300m^2 (65 feet in diameter, or about 328 square yards).
   - If average tree height is less than 20m (65 feet), then the patch diameter is equal to the average tree height.

2. The amount of area harvested per entry is directly related to the number of canopy layers to be restored. Late-successional forest in the region is uneven-aged, with a minimum of three distinct canopy layers. This means that the maximum amount harvested per entry would be one-third of the stand area, to obtain three canopy layers after three separate entries. However, since three canopy layers is a minimum, a recommended strategy is to remove 20% per entry, which would establish five canopy layers by the end of the cutting rotation.

3. The time between entries is based on a 1% annual gap-disturbance frequency, which closely resembles the natural disturbance frequency for late-successional forests in the region.[33] For example, if 100% of a stand is harvested per entry, then the time interval between entries based on a 1% annual disturbance frequency would be 100 years. If 20% of the stand is removed per entry, harvests would occur every 20 years.

The recommended patch-cutting regime for New England–Acadian Forest restoration is 20% removal every 20 years, resulting in five canopy layers over a 100-year cutting rotation. Once that rotation is completed, the stand is left to age naturally. If an alternative cutting regime is used, it should not exceed 30% of the stand area in any single entry. This ensures that canopy shade is maintained and that an uneven-age structure can develop over the cutting rotation. The following equation calculates the number of patches to create, per entry, using the three patch-cutting principles:

$$\mathbf{n} = \frac{A * x}{y}$$

where **n** is the total number of patches to be created, A is the area of the stand in m^2 (square yards), x is the percentage of area being harvested per entry (recommended at 0.2), and y is the patch size in m^2 (square yards; determined from principle 1). Note that patch size may increase as the stand grows in height, meaning that fewer patches will be required to meet the area-based target with each subsequent entry. Patches should be evenly spread throughout the stand. Any desirable tree species (columns 1–3 of Table 1) located within patches should be retained as reserve trees and left uncut. Where desirable species have been selected for crop-tree release in earlier treatments, the spatial arrangement of patches can coincide with these release areas. Patch location can also take advantage of any natural canopy openings. Although circular patches are recommended, alternative patch shapes can be used, assuming they follow the area-based guidelines from principle 1.

Structural Additions

Like the tending treatments that promote the development of multiple canopy layers, creating current and future deadwood is a recognized approach to promoting old-growth conditions that support biodiversity.[34] Although adding deadwood structure is not a treatment in itself, it is implemented during tending and regenerating treatments. Deadwood comprises both snags and downed logs, although emphasis should be placed on creating snags, which will become downed logs over time and fill the ecological roles of both. For restoration purposes, all slash and cut trees should be left in the forest. Removing wood directly competes with restoration goals; large trees are most desirable for deadwood structure, and every tree removed is a potential loss of habitat. However, if removing wood is required to offset the cost of silviculture, the following structural standards define the bare minimum of what should be considered a restoration project.


Photo: Alain Belliveau

Snags

Girdling is used to create dead standing trees (i.e., snags), which are a critical habitat requirement for a variety of wildlife. The recommended standard for snag creation is to girdle a minimum of 15 trees per hectare (6 trees per acre) that are more than 25cm (10 inches) in diameter, although doubling this amount is preferable.[35] Having at least one snag per hectare (~1 snag every 2.5 acres) larger than 50cm (20 inches) in diameter is ideal,[36] if this size criterion can be met. Generally, large trees should always be favoured over small trees as potential snags. For large-scale projects, it may be beneficial to implement tree marking before silviculture treatments are carried out, to make the snag selection process easier. For information on tools used for systematic tree girdling, see the USDA publication *Tree Girdling Tools*.[37] Follow these guidelines for girdling:

- Cut a single or double band around the entire stem, with a minimum width of 2cm (3/4 inch) per band.
- Each band should remove the bark and cambium layers entirely.
- Make the girdle below the lowest live limb on the stem.
- For safety reasons, do not girdle a tree within tree-length of an access road or trail.

Downed Logs

Felling trees, which is the typical method of implementing silviculture treatments, creates most of the deadwood in managed forests. Rotting logs provide essential habitat for many species of wildlife and also act as an important seedbed for many desirable tree species.[38] In addition to smaller trees that are cut during treatments, a minimum of 30 trees per hectare (12 per acre) that are at least 30cm (12 inches) in diameter should be cut and left onsite wherever possible.[39] Larger trees are always preferable, so if wood is being removed for economic reasons, maintaining 10 of the largest logs that are at least 2m (6 feet) in length is suggested per hectare (4 per acre).[40]

Legacy Trees

Any desirable tree species that are found during cutting treatments should be left to grow as reserve trees. However, even some undesirable species that would otherwise be cut should be left to grow old and eventually become large-diameter snags and downed logs, preferably larger than 50cm (20 inches) in diameter.[41] These are called legacy trees, and are set aside to grow old and die of natural causes. For New England–Acadian Forest restoration, legacy trees can be any of the less desirable species (columns 4 and 5 of Table 1). Exotic species, however, should not be used as legacies. Leaving at least three or four legacy trees per hectare (one or two per acre) is recommended[42]; 12 to 15 per hectare (5 to 6 per acre) is preferred.[43] The trees selected should represent the full diversity of species that occur within the stand, and selection should focus on those trees with dominant, healthy crowns. A good approach is to select and mark legacy trees before implementing any silviculture treatments so that they remain uncut and undamaged.

3
CHAPTER
Restoring Abandoned Farmland

Restoring forests on abandoned farmland has become a conservation priority in many areas of the globe, and eastern North America is no exception.[1] Beginning in the late 19th century, large areas of farmland were abandoned and subsequently followed by forest regrowth.[2] This pattern of abandonment and regrowth continues today, as can be seen by a variety of successional stages. The regrowth of forest is often considered a gain for conservation, but in the New England–Acadian Forest region, these post-agricultural forests tend to be structurally simple and support less biodiversity as compared to the natural forest communities they replaced.[3]

Almost all of the community types that occur on abandoned farmland contribute to the borealization of the New England–Acadian Forest landscape. Generally, the succession of abandoned farmland follows a predictable pattern beginning with herbaceous species, followed by woody shrubs, and ending with early-successional tree species.[4] These communities often contain remnants of their agricultural past, such as apple trees or weedy understorey plants. Although with time, abandoned farmland may naturally transition back to an original forest composition, this process would, at minimum, take multiple forest rotations over several centuries, assuming a sufficient seed source is nearby. For these reasons, "doing nothing" is not a viable restoration decision unless desirable tree species are colonizing the area naturally. Actively managing to restore late-successional forest conditions can have large gains for biodiversity in a much shorter timeframe than if the abandoned farmland is left alone.[5]

Alders, often regarded with disdain, can be highly desirable for restoring forest on abandoned farmland. They grow rapidly to form a canopy with dappled shade, can establish across a wide range of soil conditions, fix atmospheric nitrogen into the soil, and decompose rapidly to increase soil organic matter.[6] For these reasons, alders should be maintained and treated as a nurse crop wherever possible (See Appendix B for using alder as a nurse crop.) You may also need to accept a high proportion of undesirable tree species in forests that have colonized old fields. In these cases, undesirable species can be managed as a nurse crop, but their regeneration should be controlled.

Silvicultural prescriptions to restore abandoned farmland back to New England–Acadian Forest can be summarized as (1) speeding up the successional pattern on cleared land, (2) improving site occupancy with desirable tree species, (3) accelerating the growth and dominance of any desirable tree species, and (4) promoting structural diversity. The specific treatments for abandoned farmland fall into one of six scenarios that transition from recently cropped land to old-field forest. Since succession is a continuous process, your land may feature several scenarios in a patchwork, with various transitions between them.

Abandoned Farmland Scenario Key

1a. Fields devoid of trees or woody shrubs 10

1b. Not as above 11

2a. Land adjacent to rivers or streams .... Chapter 8 (pg. 61)

2b. Not as above .... Open Field (pg. 34)

3a. Abandoned fields dominated by shrubs 12

3b. Abandoned fields dominated by trees 13

4a. Abandoned fields dominated by goldenrod, hardhack, etc. .... Low Shrubland (pg. 36)

4b. Abandoned fields dominated by alder, willow, dogwood, etc. .... High Shrubland (pg. 36)

5a. > 50% of stems are of desirable species (columns 1–3 of Table 1) .... Old-Field Temperate Forest (pg. 40)

5b. Not as above 14

6a. ≥ 50% of stems are softwood species .... Old-Field Borealized Softwood (pg. 39)

6b. < 50% of stems are softwood species .... Old-Field Borealized Hardwood (pg. 38)

Open Field

Open field refers to recently abandoned fields, croplands, and pastures with herbaceous pioneer vegetation, such as broadleaf weeds and grasses, including recent crop stubble. There is a considerable amount of information available on reforesting open fields, particularly with high-value hardwoods.[7] Because hardwoods are generally more difficult to establish than conifers,[8] the prescriptions below will serve for both. These prescriptions focus on establishing a new forest community but also include two tending prescriptions.

Prescription 1: Plowing and Disking. Plow and disk the entire restoration site where possible. In some cases, it may be beneficial to plow and disk the site multiple times, as this will reduce the need for weed control in the future.

Prescription 2: Planting. Whether you are using the blanket or island planting strategy (see Chapter 2), trees should be spaced at roughly 2m by 2m, or 2,500 trees per hectare (6 by 6 feet, or ~1,000 trees per acre). Rather than planting in straight, even rows, consider planting irregularly to mimic a natural forest.

With the exception of Red Spruce, planting shade-tolerant species in an open field is not recommended. Table 3 suggests a simplified mix of desirable tree species to establish on old-field sites. This mix is based on research that has confirmed the species' ability to naturally colonize fields[9] or become established through planting on old fields.[10] A mix of species should be planted in a random fashion rather than in a defined pattern by species. Remove any clumps of sod from the planting holes and pile them up throughout the restoration site to create mound features. Adding compost to the planting holes can give the trees an added boost, particularly on poor sites.

Table 3. Simplified planting mixes on abandoned farmland, by soil nutrient status

Soil nutrients	Species mix
Poor	Eastern White Pine | Red Oak
Medium	Eastern White Pine | Red Oak | Red Spruce
Rich	Eastern White Pine | Red Oak | Red Spruce | Eastern White Cedar | White Ash

Prescription 3: Weeding. Vegetation control is essential for at least the first three years after planting. Grasses in particular will compete vigorously for soil moisture and nutrients and also provide habitat for rodents that may girdle young trees. The dense spacing will help control weeds once canopy closure is established, but until then, weeds must be controlled manually or mechanically. The most successful weed control consists of between-row tilling plus mowing around individual trees once a month from May to September. Alternatively, applying bark mulch in a 15cm to 25cm (6-to-10-inch) radius around planted trees will help control competing vegetation.

Prescription 4: Pruning. Generally, the dense spacing should limit the need for pruning. However, if forking and branching are observed, strategic pruning can greatly improve upward growth and form in early development stages. Prune in winter, when trees are dormant, and only after the third growing season, once the trees have established healthy root systems. The priority in pruning is to remove multiple leaders, favouring the healthy, dominant one. An optional treatment is to prune the lowest branches on 100 to 200 crop trees per hectare (40 to 80 trees per acre) in the third year after planting, and every two or three years afterward until the stand reaches the stratification stage. This will promote good form in a select group of trees that will develop into the dominant canopy layer.

Prescription 5: Crop-Tree Release. Once the planted trees reach the stem exclusion stage, an optional crop-tree release can be implemented. A target of 100 to 200 crop trees per hectare (40 to 80 trees per acre), including any that have been pruned, will promote establishment of a multilayered canopy. Select as crop trees those with healthy, dominant crowns and good stem form. All species in the planting mix should be represented in the crop-tree selection if possible.

Prescription 6: Underplanting. Once the forest reaches the understorey development stage, additional species can be planted. Use the species mixes in Table 2. Underplanting whenever and wherever a canopy opening or dappled shade occurs will facilitate the development of an uneven-aged forest structure. As a rule, plant trees a minimum of 1m (3 feet) away from previously established and newly planted trees.

Low Shrubland

After three or so years of abandonment, farmland often begins to colonize with perennials that will replace the herbaceous pioneer species.[11] Common indicators of low shrubland are goldenrods and members of the genus *Spirea*, such as Hardhack and Meadowsweet. These species can form deep root systems that require aggressive site preparation to be destroyed. The prescriptions for low shrubland are generally the same as for open field but differ in that the site may need to be bush-hogged before plowing and disking.

Prescription 1: Mowing or Bush Hogging. The decision to mow or bush-hog depends on the degree of colonization, but some form of vegetation control may be needed before plowing and disking. Mowing or bush hogging in late summer is best for clearing field vegetation and restricting its ability to regrow. If a second treatment can be applied, do it in midautumn to reinforce the intended outcome. Keeping the mower deck height above 15cm (6 inches) helps avoid damage to any ground-nesting wildlife.

Prescription 2: Plowing and Disking. Refer to Open Field prescription 1.

Prescription 3: Planting. Refer to Open Field prescription 2.

Prescription 4: Weeding. Refer to Open Field prescription 3.

Prescription 5: Pruning. Refer to Open Field prescription 4.

Prescription 6: Crop-Tree Release. Refer to Open Field prescription 5.

Prescription 7: Underplanting. Refer to Open Field prescription 6.

High Shrubland

The next stage of old-field succession is high shrubland, which is composed of woody shrubs that generally grow taller than 1m (3 feet). The most common indicator of high shrubland is alder, which readily invades old fields across a variety of soil conditions. Other shrubs may include apples, hawthorns, willows, serviceberries, and Red-Osier Dogwood, depending on site characteristics. Regardless of the composition, the prescriptions for high shrubland focus on maintaining shrubs to act as a nurse crop for desirable shade-tolerant tree species.[12]

Prescription 1: Culling. Undesirable conifers often colonize high shrubland, but for restoration purposes, alder is a better nurse crop. To limit competition, any species in column 5 of Table 1 can be culled if it occurs in areas containing alder. Boreal conifers in particular should be removed lest they replace the shade-intolerant alder. In areas devoid of alder, however, undesirable tree species can be left alone to continue discouraging the growth of herbaceous field vegetation.

Prescription 2. Weeding. If shrubs are very dense, you may need to weed in strips to facilitate planting and access to the desirable trees. This can be done manually, or using a bush hog. Weeding can also be done within a 1m (3-foot) radius of natural or planted desirable species after prescription 3 is implemented.

Prescription 3: Underplanting. Plant in the understorey, following the species mixes in Table 2. Underplanting can be done frequently wherever alders colonize. As a rule, plant trees 2m (6 feet) apart, and roughly 1m (3 feet) away from alder clumps, where possible.

Prescription 4: Cleaning. Once planted trees are established—after a minimum of two growing seasons—the stand can be cleaned to release desirable species from overtopping shrubs. Shrubs that are not directly overtopping desirable trees can be left alone for underplanting in the future.

Prescription 5: Pruning. The same as Open Field prescription 4, this applies to any desirable species in high shrubland, whether planted or naturally colonized. Prune any desirable trees that have multiple leaders, and remove the lower 50% of branches on "cabbage" trees to promote vertical growth.

Prescription 6: Crop-Tree Release. Refer to Open Field prescription 5.

Prescription 7: Underplanting. Refer to Open Field prescription 6.

Old-Field Borealized Hardwood

These forest communities, typically associated with medium-rich soils on moist sites, are most often composed of Trembling Aspen, Grey Birch, and/or Pin Cherry, with lesser amounts of other shade-intolerant hardwoods. The nature of this community often allows desirable species and Balsam Fir to colonize in the understorey, since the dappled canopy created by the hardwoods provides nurse conditions for shade-tolerant regeneration.[13] For more details on this forest community, refer to OF5[14] in the Forest Ecosystem Classification for Nova Scotia.[15] The prescriptions below aim to favour desirable tree species while maintaining canopy closure of early-successional hardwoods. Maintaining canopy closure limits woody and herbaceous competition and discourages stump sprouting of intolerant hardwoods after cutting.

Prescription 1: Cleaning. Implement cleaning during the initiation stage to favour any desirable species that have naturally colonized. Undesirable hardwoods that are not directly overtopping desirable trees (columns 1–3 of Table 1) can be left to compete naturally. Cleaning can be done at intervals until the stand reaches the exclusion stage.

Prescription 2: Crop-Tree Release with Spacing. In the exclusion and stratification development stages, implementing a crop-tree release with spacing favours any desirable tree species that may have naturally established while increasing the growth of residual hardwoods. Select as crop trees any species in columns 1–3 of Table 1, regardless of canopy position. Density of non–crop trees should not fall below 1,700 stems per hectare, or 2.4m-by-2.4m spacing (690 stems per acre, or 8-by-8-foot spacing).

Prescription 3: Underplanting. If a seed source is not available to regenerate desirable species naturally, plant a variety of species in the fresh-moist and medium-rich soil classes listed in Table 2. Underplanting can be done at any time after prescription 2. As a rule, plant trees 3m apart, and approximately 1m away from any residual hardwood stems, where possible.

Prescription 4: Weeding. Old-field borealized hardwood communities tend to have a well-developed shrub and herbaceous layer in the understorey due to the dappled shade of the canopy. Weeding may therefore be required within a 1m (3-foot) radius of established regeneration, both natural and planted. Weeding may be needed multiple times until desirable tree species overtop the competing vegetation.

Prescription 5: Release Cutting. Once desirable species are established and exceed 1m (3 feet) in height, overstorey hardwoods can be systematically removed. The release cutting should be done in stages wherever patches of desirable tree species successfully establish. Before cutting, ensure that the structural addition criteria described in Chapter 2 will be met.

Old-Field Borealized Softwood

This is the most common forest community to colonize abandoned farmland in the region. Such communities are typically dominated by White Spruce on upland sites and Tamarack on wetter sites, and they commonly contain a strong Balsam Fir component.[16] There is often little to no understorey in these communities, other than herbaceous vegetation on wet sites. For more details on these forest communities, refer to OF1,[17] OF2,[18] and OF4[19] in the Forest Ecosystem Classification for Nova Scotia.[20] Restoration of old-field borealized softwood focuses on favouring any desirable species that may have naturally established, while opening up the residual canopy for natural or planted regeneration.

Prescription 1: Cleaning. Implement cleaning during the initiation stage to favour any desirable species that have naturally colonized. Undesirable conifers that are not directly overtopping desirable trees (columns 1–3 of Table 1) can be left to compete naturally. Cleaning can be done at intervals until the stand reaches the exclusion stage.

Prescription 2: Crop-Tree Release. Release crop trees during the exclusion and stratification development stages. Select as crop trees any species in columns 1–3 of Table 1, regardless of canopy position.

Prescription 3: Pruning. Pruning can be done in conjunction with crop-tree release during the exclusion development stage. Prune any open-grown crop-trees with multistemmed leaders to a single, dominant leader. On "cabbage" trees, prune the bottom 50% of the live crown to encourage good stem form.

Prescription 4: Patch Cutting. Patch cutting is recommended in the stratification and understorey stages of development. Within patches, target for removal all species in columns 4 and 5 of Table 1. The spatial arrangement of patches can coincide with released areas for crop trees (prescription 2), leaving any desirable species (columns 1–3 of Table 1) as reserve trees within patches. Before cutting, ensure that the structural addition criteria described in Chapter 2 will be met.

Prescription 5: Tilling. If a desirable seed source is available, it may be beneficial to scarify the ground in the canopy openings created after patch cutting, to prepare the site for regeneration.

Prescription 6: Fill Planting. If a desirable seed source is not available, fill planting may be required in the open patches. Use the species mixes listed in Table 2 and plant trees at a spacing of 3m by 3m (10 by 10 feet).

Prescription 7: Weeding. Although the patch size criteria should generally provide enough shade to limit competing vegetation, monitor the regeneration. If necessary, weed within a 1m (3-foot) radius of the established regeneration, both natural and planted.

Old-Field Temperate Forest

Old-field temperate forest communities are typically dominated by Eastern White Pine or Eastern White Cedar and, depending on the development stage and site conditions, may contain other desirable species as well, including hardwoods.[21] However, these stands may also have a significant amount of undesirable species, particularly White Spruce, Balsam Fir, and/or Tamarack. Many trees may have poor form and lack vigour because of the open conditions in which they established. For more details on these forest communities (with the exception of cedar), refer to OF3[22] in the Forest Ecosystem Classification for Nova Scotia.[23] Since the species composition of this scenario is generally favourable, restoration of old-field temperate forest focuses on maintaining a dominant canopy of desirable species, increasing growth of good-quality stems, and transitioning toward a mixedwood condition over time.

Prescription 1: Culling. Implement culling only during the initiation and exclusion development stages. By definition, the old-field temperate softwood community contains less than half undesirable species, and therefore up to 60% of undesirable stems (of the species listed in column 5 of Table 1) should be culled. This will equate, at maximum, to removing 30% of the current growing stock, which will give desirable species a competitive advantage during the early stages of development.

Prescription 2: Pruning. Pruning can be implemented during the exclusion development stage. Prune any open-grown desirable trees that have multiple leaders, and remove the lower 50% of branches on any open-grown “cabbage” trees to promote upward growth.

Prescription 3: Crop-Tree Release with Spacing. Crop-tree release with spacing is best implemented in the stratification and understorey development stages, once desirable trees begin to exhibit dominance. Select as crop trees those with healthy, dominant crowns and good stem form. All desirable species (columns 1–3 of Table 1) represented in the old-field temperate forest community should be included in the crop-tree selection, regardless of canopy position. If patches of undesirable species exist, the density between non–crop trees should not fall below 1,700 stems per hectare, or 2.4m-by-2.4m spacing (~690 stems per acre, or 8-by-8-foot spacing).

Prescription 4: Underplanting. To increase the diversity of desirable species in the old-field community, underplant once the stand reaches the understorey stage. Plant the species mixes listed in Table 2, emphasizing those not already represented in the stand. Rather than creating openings that remove desirable tree species, take advantage of any natural openings or areas cleared during the crop-tree release with spacing treatment. Plant in openings at 3m-by-3m (10-by-10-foot) spacing, and 1m (3 feet) from any established trees.

4
CHAPTER
Restoring Conifer Plantations

Conifer plantations have been widely established across the New England–Acadian Forest region, both in industrially managed forests and on private woodlots. Conifer plantations are useful when the aim is to maximize timber production for economic values, but a growing body of evidence suggests that conifer plantations can negatively impact biodiversity, at both stand and landscape scales.[1] In the New England–Acadian Forest region, conifer plantations have been shown to decrease the abundance and diversity of amphibians,[2] bryophytes,[3] and vascular plants.[4] They are also known to decrease the breeding success of some songbirds and act as barriers to movement for other wildlife species.[5] They are often established as monocultures and managed to exclude any tree species that might naturally colonize the plantation. Even in multispecies plantations, hardwoods are often treated as undesirable competitors, and those that do manage to colonize are typically undesirable species.[6]

Restoring conifer plantations to native forest communities for the benefit of biodiversity has been a growing trend, particularly in highly fragmented regions such as southern Ontario,[7] Japan,[8] and Europe.[9] In eastern Canada, underplanting and fill planting in conifer plantations is recognized as an important silvicultural tool for restoring late-successional forest communities.[10]

The prescriptions for restoring conifer plantations are based on four general concepts: (1) favouring desirable species over undesirable and exotic species, (2) using existing growing stock as a nurse crop,[11] (3) increasing the growth rate of residual trees, and (4) promoting structural diversity.

Conifer Plantation Scenario Key

1a. Plantations composed of native species 10
1b. Plantations composed of nonnative species.................... Exotic Conifer Plantation (pg. 44)

2a. Stems >50% undesirable species
(columns 4–5 of Table 1)..Borealized Conifer Plantation (pg. 45)
2b. Stems >50% desirable species
(columns 1–3 of Table 1)..Temperate Conifer Plantation (pg. 45)

Exotic Conifer Plantation

Plantations of exotic species are treated similar to borealized conifer plantations, but prescriptions aim to remove exotic species as quickly as possible by favouring any native species over exotics. Some exotic conifers can become invasive once they reach reproductive age and may outcompete native species. Although a variety of species have been planted experimentally across the region, common exotic conifers include Scots Pine, Norway Spruce, and Japanese and European Larch. Prescriptions emphasize reducing the proportion of exotic conifers in the stand while maintaining canopy closure to provide desirable species with nurse conditions.

Prescription 1: Culling. This treatment can be implemented during all development stages. Cull trees are defined as any regeneration of exotic conifers. Culling of exotic regeneration should be implemented regularly until all exotic trees have been removed over the course of treatments.

Prescription 2: Crop-Tree Release with Spacing. In the exclusion development stage, implementing a crop-tree release with spacing will favour any native trees that may have naturally established, reduce the number of exotic conifers, and increase the growth of all residual stems. Select as crop trees any species in Table 1, regardless of canopy position. Spacing may not be required depending on the initial plantation density, but if used, density between non–crop trees should not fall below 1,700 stems per hectare, or 2.4m-by-2.4m spacing (~690 stems per acre, or 8-by-8-foot spacing).

Prescription 3: Patch Cutting. Patch cutting is recommended in the stratification and understorey stages of development. Target for removal exotic conifers and any undesirable species from columns 4 and 5 of Table 1. The spatial arrangement of patches can coincide with released areas for crop trees (prescription 2), leaving any desirable species (columns 1–3 of Table 1) as reserve trees within patches.

Prescription 4: Tilling. If a desirable seed source is available, it may be beneficial to scarify the ground in the canopy openings created after patch cutting, to prepare the site for regeneration.

Prescription 5: Fill Planting. If a desirable seed source is not available, fill planting may be required in the open patches. Use the species mixes listed in Table 2 and plant trees at a spacing of 3m by 3m (10 by 10 feet).

Prescription 6: Weeding. Although the patch size criteria should generally provide enough shade to limit competing vegetation, monitor the regeneration. If necessary, weed within a 1m (3-foot) radius of established regeneration, both natural and planted.

Borealized Conifer Plantation

Borealized conifer plantations are commonly composed of White Spruce, Balsam Fir, Black Spruce, Tamarack, or Jack Pine. They are often planted as monocultures or as multispecies plantations, which sometimes include temperate species. If temperate species are included in the species mix, refer to Temperate Conifer Plantations (below) for recommendations on conserving native genetic stock. Similar to old-field borealized softwood communities, restoration of borealized conifer plantations focuses on favouring desirable species while opening up the residual canopy.

Prescription 1: Cleaning. Implement cleaning during the initiation stage to favour any desirable species that may have naturally colonized the plantation. Plantation conifers that are not directly overtopping desirable trees (columns 1–3 of Table 1) can be left to compete naturally. Cleaning can be done at intervals until the stand reaches the exclusion stage.

Prescription 2: Crop-Tree Release. Release crop trees during the exclusion and stratification development stages. Select as crop trees any species in columns 1–3 of Table 1, regardless of canopy position.

Prescription 3: Patch Cutting. Patch cutting is recommended in the stratification and understorey stages of development. Target for removal all species in columns 4 and 5 of Table 1. If the genetic stock of the plantations is known to be native, select two or three legacy plantation conifers per hectare (1 or more per acre) that will remain uncut. The spatial arrangement of patches can coincide with released areas from prescription 2, leaving any desirable species (columns 1–3 of Table 1) as reserve trees within patches. Before cutting, ensure that the structural addition criteria described in Chapter 2 will be met.

Prescription 4: Tilling. Refer to Exotic Conifer Plantations prescription 4.

Prescription 5: Fill Planting. Refer to Exotic Conifer Plantations prescription 5.

Prescription 6: Weeding. Refer to Exotic Conifer Plantation prescription 6.

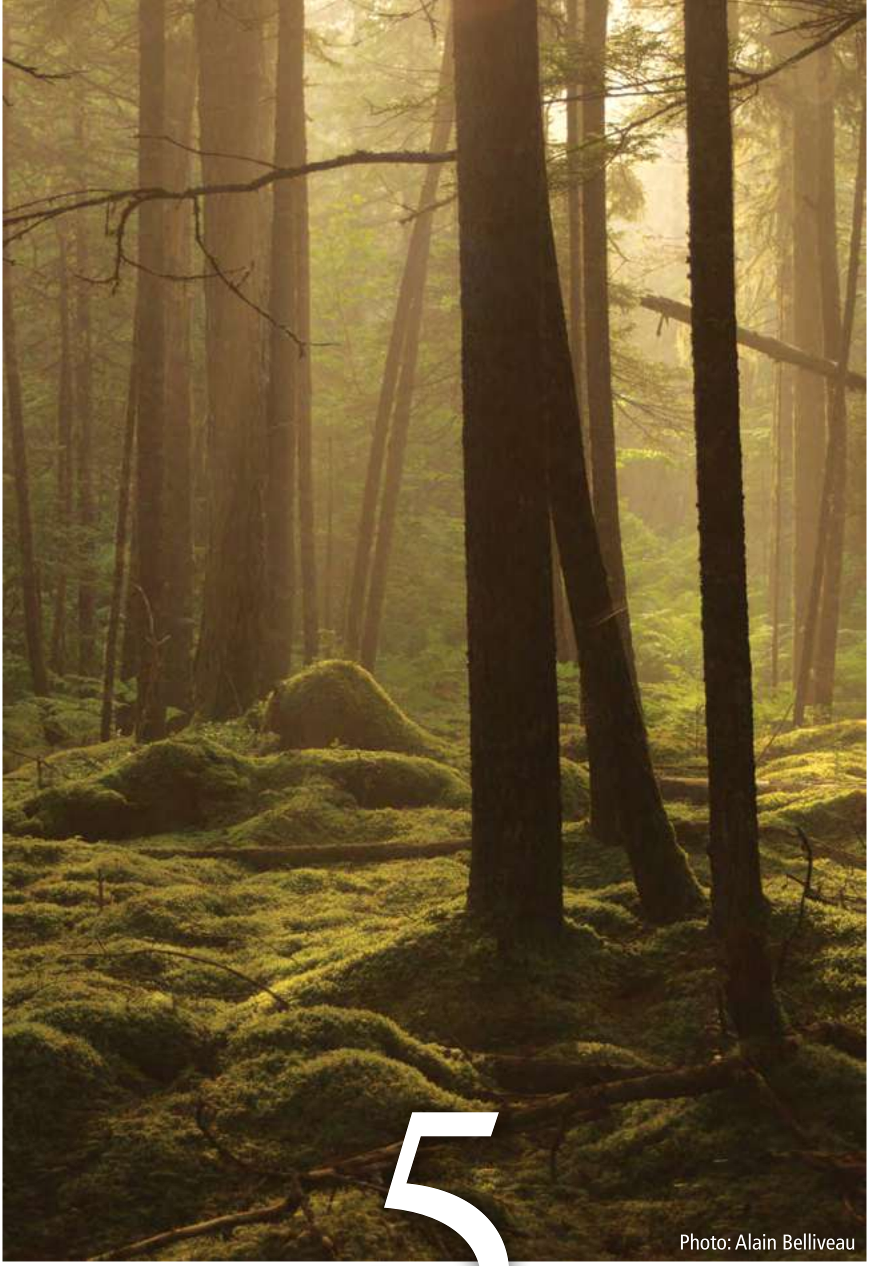
Temperate Conifer Plantation

Temperate conifer plantations are most often composed of White Pine or Red Pine; plantations of Red Spruce have also been used in some locations. Although these are all native species, the plantations have been commonly established using nonnative genetic stock. Because genes are the basic unit of biodiversity, maintaining native genetic diversity is essential for successful forest conservation and restoration. For these reasons, if the genetic stock is known to be nonnative (defined as any seed source from outside the Northeast[12]), it should be considered an exotic conifer plantation and treated as such. If the genetic stock is unknown, treat it as either an exotic or a borealized conifer plantation and plan to replace the entire stand over the course of a cutting rotation. However, if planted trees are known to be of native genetic stock, use the following treatments to maintain a dominant composition of desirable species, diversify the species mix, and promote structural diversity.

Prescription 1: Culling. Implement culling only during the initiation and exclusion development stages. By definition, the temperate conifer plantation has less than 50% undesirable species (column 5 of Table 1), and therefore up to 60% of undesirable stems should be culled. This will equate, at maximum, to removing 30% of the current growing stock, which will give desirable species a competitive advantage during the early stages of development.

Prescription 2: Crop-Tree Release with Spacing. Crop-tree release with spacing is best implemented in the stratification and understorey development stages, once desirable trees begin to exhibit dominance. All desirable tree species (columns 1–3 of Table 1) represented in the temperate conifer plantation should be included in the crop-tree selection, regardless of canopy position. Spacing may not be required, depending on the initial plantation density, but if used, density between non–crop trees should not fall below 1,700 stems per hectare, or 2.4-by-2.4m spacing (~690 stems per acre, or 8-by-8-foot spacing).

Prescription 3: Underplanting. To increase the diversity of desirable species in temperate conifer plantations, underplant once the stand reaches the understorey stage. Plant the species mixes listed in Table 2, emphasizing those not already represented in the stand. Rather than creating openings that remove desirable tree species, take advantage of any natural openings or areas cleared during the crop-tree release with spacing treatment. Plant in openings at a 3m-by-3m (10-by-10-foot) spacing, and 1m (3 feet) from any established trees.



5

CHAPTER

Restoring Borealized Clearcuts

Clearcutting, the dominant form of forest harvesting across the New England–Acadian Forest region, has significantly contributed to the borealization of the landscape. Clearcutting removes most or all trees in a single entry,[1] often over large areas. The open and exposed nature of clearcuts restricts the ability of most shade-tolerant species to regenerate.[2] Instead, exposure-resistant, boreal-like forest communities tend to replace late-successional ones; hence the continual, ongoing decline of these communities across the landscape.[3] Clearcutting is followed by a decline in structural complexity[4] and a significant loss of the genetic diversity that has allowed tree species to adapt to natural environmental change over time.[5] The boreal-like communities that may form after clearcutting vary, depending on geographic and environmental factors. As part of their composition, they may contain some desirable species, whether as residual trees after clearcutting, early colonizers, or regrowth from stump sprouting.

Silvicultural prescriptions to restore borealized clearcuts to New England–Acadian Forest communities focus on (1) accelerating the growth and dominance of any desirable tree species, (2) using undesirable growing stock as a nurse crop, and (3) promoting structural diversity. For restoration purposes, post-clearcut communities are grouped into three scenarios.

Clearcut Scenario Key

1a. > 50% of stems are desirable species (columns 1–3 of Table 1) .... Post-Clearcut Temperate Forest (pg. 51)

1b. Not as above 10

2a. ≥ 50% of stems are softwood species .... Borealized Softwood (pg. 49)

2b. < 50% of stems are softwood species .... Borealized Hardwood or Mixedwood (pg. 50)

Borealized Softwood

Borealized softwood communities are most often dominated by Balsam Fir, either alone or with White Spruce, Black Spruce, or Tamarack. If present, hardwoods are typically White Birch, aspens, or Red Maple. Some communities may also contain a significant amount of Red Spruce, and depending on the development stage and available seed source, other desirable species may regenerate in the understorey. However, Balsam Fir usually dominates the regenerating canopy layer in older communities. For more details on these forest communities, refer to SH5,[6] SH6,[7] SH7,[8] SH8,[9] and SH10[10] in the Forest Ecosystem Classification for Nova Scotia.[11] Restoration of borealized softwood focuses on favouring any desirable species while opening up the residual canopy for regeneration.

Prescription 1: Cleaning. Implement cleaning during the initiation stage to favour any desirable tree species that have naturally colonized. Undesirable species that are not directly overtopping desirable trees (columns 1–3 of Table 1) can be left to compete naturally. Cleaning can be done at intervals until the stand reaches the exclusion stage.

Prescription 2: Crop-Tree Release. Release crop trees during the exclusion and stratification development stages. Select as crop trees any species in columns 1–3 of Table 1, regardless of canopy position.

Prescription 3: Patch Cutting. Patch cutting is recommended in the stratification and understorey stages of development. Target for removal all species in columns 4 and 5 of Table 1. The spatial arrangement of patches can coincide with released areas for crop trees (prescription 2), leaving any desirable tree species (columns 1–3 of Table 1) as reserve trees within patches. Before cutting, ensure that the structural addition criteria described in Chapter 2 will be met.

Prescription 4: Tilling. If a desirable seed source is available, it may be beneficial to scarify the ground in the canopy openings created after patch cutting, to prepare the site for regeneration.

Prescription 5: Fill Planting. If a desirable seed source is not available, fill planting may be required in the open patches. Use the species mixes listed in Table 2 and plant at a spacing of 3m by 3m (10 by 10 feet).

Prescription 6: Weeding. Although the patch size criteria should generally provide enough shade to limit competing vegetation, monitor the regeneration. If weeding is necessary, weed within a 1m (3-foot) radius of the established regeneration, both natural and planted.

Borealized Hardwood or Mixedwood

Borealized hardwood and mixedwood communities are most often dominated by intolerant hardwoods and Red Maple, but may have a strong softwood component of Balsam Fir and / or Red Spruce. Intolerant hardwood communities often allow desirable species and Balsam Fir to colonize in the understorey because the dappled canopy created by the hardwoods provides nurse conditions for shade-tolerant regeneration.[12] For more details on these forest communities, refer to MW2,[13] MW4,[14] MW5,[15] IH1,[16] IH3,[17] IH4,[18] IH5,[19] IH6,[20] and IH7[21] in the Forest Ecosystem Classification for Nova Scotia,[22] and Early Successional Forest[23] in the Natural Landscapes of Maine.[24] The prescriptions below aim to favour desirable tree species while maintaining canopy closure of undesirable hardwoods. Maintaining canopy closure provides dappled shade, limiting woody and herbaceous competition and discouraging stump sprouting of intolerant hardwoods after cutting.

Prescription 1: Cleaning. Implement cleaning during the initiation stage to favour any desirable species that have naturally colonized. Undesirable species that are not directly overtopping desirable trees (columns 1–3 of Table 1) can be left to compete naturally. Cleaning can be done at intervals until the stand reaches the exclusion stage.

Prescription 2: Crop-Tree Release with Spacing. Release crop trees in the exclusion and stratification development stages to favour any desirable tree species that may have naturally established and to increase the growth of residual stems. Select as crop trees any species in columns 1–3 of Table 1, regardless of canopy position. Density between non–crop trees should not fall below 1,700 stems per hectare, or 2.4m-by-2.4m spacing (~690 stems per acre, or 8-by-8-foot spacing). When spacing between crop trees, select Red Maple for release over other undesirable species wherever possible. Coppice clumps of crop trees or Red Maple should be thinned to one or two dominant, healthy stems of low-stump origin.

Prescription 3: Underplanting. If a seed source is not available to regenerate desirable tree species, underplant a mix of species from Table 2. Underplanting can occur at intervals over time. Plant trees with 3m-by-3m (10-by-10-foot) spacing and approximately 1m (3 feet) away from established stems where possible.

Prescription 4: Weeding. Borealized hardwood and mixedwood communities tend to have a well-developed shrub and herbaceous layer in the understorey because of the dappled shade of the canopy. Weeding may therefore be required multiple times within a 1m (3-foot) radius of established regeneration, both natural and planted, until desirable tree species overtop the competing vegetation.

Prescription 5: Release Cutting. Once desirable tree species are established and exceed 1m (3 feet) in height, undesirable species in the overstorey can be systematically removed. The release cutting should occur in stages wherever patches of desirable species successfully establish. Before cutting, ensure that the structural addition criteria described in Chapter 2 will be met.

Post-Clearcut Temperate Forest

Post-clearcut temperate forest usually occurs when young Red Spruce, White Pine and other desirable species are released after clearcutting, or when tolerant hardwood species regenerate as coppice. Since the species compositions of this scenario are generally favourable, restoration of post-clearcut temperate forest focuses on maintaining a dominant canopy of desirable species, increasing growth of quality stems, and reintroducing species that may have been lost to clearcutting.

Prescription 1: Culling. Implement culling only during the initiation and exclusion development stages. By definition, the post-clearcut temperate forest is less than 50% undesirable species (column 5 of Table 1), and therefore up to 60% of undesirable stems should be culled. This will equate, at maximum, to removing 30% of the current growing stock, which will give desirable species a competitive advantage during the early stages of development.

Prescription 2: Crop-Tree Release with Spacing. Crop-tree release with spacing is best implemented during the stratification development stage, once desirable trees begin to exhibit dominance. A target of 100 to 200 crop trees per hectare (40 to 80 trees per acre) is recommended. Select as crop trees those with healthy, dominant crowns and good stem form. All desirable species (columns 1–3 of Table 1) represented in the species mix should be included in the crop-tree selection, regardless of canopy position. Density between non–crop trees should not fall below 1,700 stems per hectare, or 2.4m-by-2.4m spacing (~690 stems per acre, or 8-by-8-foot spacing). When spacing between crop trees, select Red Maple over other undesirable species wherever possible. Coppice clumps of crop trees or Red Maple should be thinned to one or two dominant, healthy stems of low-stump origin.

Prescription 3: Underplanting. To increase the diversity of desirable species in a post-clearcut temperate forest, underplant the species mixes listed in Table 2, emphasizing species not already represented in the stand. Rather than creating openings that remove desirable species, take advantage of natural openings or those created during the crop-tree release with spacing treatment. Underplanting can be done at intervals over time. Plant in openings at 3m-by-3m (10-by-10-foot) spacing, and approximately 1m (3 feet) away from established stems where possible.

6
CHAPTER
Restoring High-Graded Forests

High-graded forests usually have a long history of improper logging; the "best trees" were cut, and anything undesirable was left behind.[1] The definition of "best trees" has changed over time, starting with the largest and straightest White Pine for ship masts during the colonial era, softwood lumber and pulp throughout the industrial revolution, and veneer-quality hardwoods into the present day. New England–Acadian Forest communities that have been high-graded are often replaced by communities dominated by Red Maple, Balsam Fir, or other short-lived, early-successional species.[2] Restorative silviculture in these forests is often limited, and prescriptions will be similar regardless of the community being restored. Unlike the other restoration scenarios, which are defined by species compositions, high-grades are defined by residual structure. To identify a high-grade, look for the following signs[3]:

- The distribution of trees is highly variable, with poor stocking, patchy clumps of trees, and/or open areas devoid of trees.
- Although the forest may have trees of various sizes and ages, older and larger trees often have poor form and lack vigour.
- What little regeneration exists may occur in a patchy distribution, with young hardwoods in clumps originating from stump sprouts.
- Evidence of past cutting—old stumps, skid trails, and damage to residual trees—may be apparent.

When making choices on which trees to leave or cut, keep the following points in mind:

- Trees with poor growth or form are not necessarily undesirable. They may provide wildlife habitat, act as a seed source, or as a nurse crop for regeneration of desirable species.
- You may need to accept a high proportion of undesirable tree species where the forest composition currently lacks desirable species. In these cases, you can manage undesirable trees as a nurse crop while controlling their regeneration. Where possible, favour Red Maple over other species, as Red Maple can contribute to old-growth structure when mature.
- In high-grades dominated by tolerant hardwoods, give special attention to areas with a high proportion of Beech. Additional information on Beech management appears in Appendix A.

Silvicultural prescriptions to restore high-graded forests to healthy New England–Acadian Forest communities focus on four general concepts: (1) improving site occupancy with desirable tree species, (2) accelerating the growth of desirable tree species, (3) where possible, reducing the proportion of undesirable tree species, (4) promoting structural diversity.

Because high-grades have variable conditions related to tree stocking and size distribution, no single set of treatments to restore high-graded stands can be prescribed.[4] To start, get a clear sense of the conditions of the stand, approximate the amount of area in each scenario, and note their spatial arrangement. You may find examples of all scenarios in small patches within the larger high-graded area. The key below follows a multi-treatment approach[5] that attempts to make use of any existing growing stock. Each restoration scenario can be repeated as the high-graded patches progress over time until a self-sustaining New England–Acadian Forest community is established.

High-Grade Scenario Key

1a. Patches devoid of trees.. High-Grade Scenario C (pg. 56)
1b. Not as above..10

2a. Patches of stratified trees ≥10cm (4 inches) in diameter .....High-Grade Scenario A (pg. 55)
2b. Patches of trees <10cm (4 inches) in diameter ....High-Grade Scenario B (pg. 50)

High-Grade Scenario A

This high-grade scenario has good potential as the foundation for a future New England–Acadian Forest community. Ideally, the existing trees will form an upper canopy layer over time, allowing a new canopy layer to establish from advance regeneration or planted stock. If desirable tree species (columns 1–3 of Table 1) are not present, residual trees should be managed as a nurse crop. Release desirable tree species wherever possible, but otherwise manage the stand to maximize the growth potential of any healthy stems. Advanced regeneration occurring as an understorey component should be treated according to the prescriptions for High-Grade Scenario B.

Prescription 1: Crop-Tree Release with Spacing. Select as crop trees any species in columns 1–3 of Table 1 that are 10cm (4 inches) in diameter or larger. Unless they pose a safety concern, all species in columns 1–3 should remain uncut, even if two or more are in competition, with the exception of coppice clumps. Coppice clumps of crop trees or Red Maple should be thinned to one or two dominant, healthy stems of low-stump origin. When spacing between crop trees, Red Maple can be selected for release over other undesirable species, but releasing trees with healthy crowns is paramount. Although spacing will be irregular because of the variability of tree cover throughout the area, average density between non–crop trees should not fall below 1,700 stems per hectare, or 2.4-by-2.4m spacing (~690 stems per acre, or 8-by-8-foot spacing), where possible.

Prescription 2: Pruning. Any open-grown trees with forked, crooked, deformed, or diseased leaders can be pruned to a single dominant leader. This will promote height growth and improve tree health.

Prescription 3: Underplanting. To reintroduce species that may have been removed during high-grading, underplant a variety of desirable species from Table 2. Rather than creating openings that remove desirable growing stock, take advantage of any natural openings or areas cleared during the crop-tree release with spacing treatment. Underplanting can be done at intervals over time as openings occur. Plant in openings at 3m-by-3m (10-by-10-foot) spacing and approximately 1m (3 feet) away from established stems.

High-Grade Scenario B

In this scenario, advance regeneration is present, either in an open setting lacking an overstorey canopy, or in conjunction with Scenario A as an understorey component. Management of advance regeneration should focus on favouring desirable tree species or, if these are not present, maintaining site occupancy of undesirable species. Treatments in Scenario B can be implemented at intervals until the patches meet the Scenario A definition.

Prescription 1: Cleaning. Cleaning can be implemented in the initiation stage. Favour any desirable species that have naturally colonized. Any undesirable species that are not directly overtopping desirable trees (columns 1–3 of Table 1) can be left to maintain site occupancy. Cleaning can be done at intervals until the stand reaches the exclusion stage.

Prescription 2: Crop-Tree Release. Crop-tree release can be implemented during the exclusion development stage. Select as crop trees any species in columns 1–3 of Table 1, as well as Red Maple, regardless of canopy position. Any coppice should be thinned to two or three dominant, healthy stems of low-stump origin.

Prescription 3: Pruning. Pruning can be done in conjunction with crop-tree release. Prune any crop trees that have lower live branches or multiple leaders. Additionally, any undesirable conifers growing in the open with multiple leaders or "cabbage" growth can also be pruned to encourage height growth. Multistemmed leaders should be pruned to a single, dominant one.

High-Grade Scenario C

In this worst-case scenario, patches within the high-grade are devoid of trees. The openness of these patches often invites high competition from herbaceous vegetation, most notably ferns, which keep regeneration from establishing. Treatments in Scenario C therefore focus on destroying herbaceous competition and establishing desirable species. These prescriptions can be implemented regularly until patches meet the Scenario B definition.

Prescription 1: Mowing. Preparing the site by mowing ferns after full expansion of the fronds in spring, and again in late summer, has been shown to significantly improve regeneration.[6] However, care must be taken not to disturb the forest floor when mowing, as this will stimulate further sprouting of ferns.

Prescription 2: Planting. If an adequate seed source of desirable species is available, one option is to wait a year following site preparation to see whether the patches might regenerate naturally. If not, the only option for establishing regeneration is planting. Plant a variety of desirable tree species from Table 2 at 2m-by-2m (6-by-6-foot) spacing, for 2,500 trees per hectare (~1,000 trees per acre). If the openings are larger than 300m^2 (340 square yards), shade-tolerant species (with the exception of Red Spruce) are not likely to succeed. Instead, use a simplified mix of desirable species, as listed in Table 3, for large open areas. Where dense fern cover is a concern, planting stock should be at least 30cm (12 inches) high, but 1m (3 feet) or taller is ideal.

Prescription 3: Weeding. Although the dense spacing will discourage weeds once canopy closure is established, controlling ferns for the first 2-3 years after planting is essential. However, similar to preparing the site by mowing, care must be taken not to disturb the forest floor when weeding, as this will further stimulate sprouting of ferns. The most successful fern control consists of mowing after full expansion of the fronds in spring, and again in late summer.

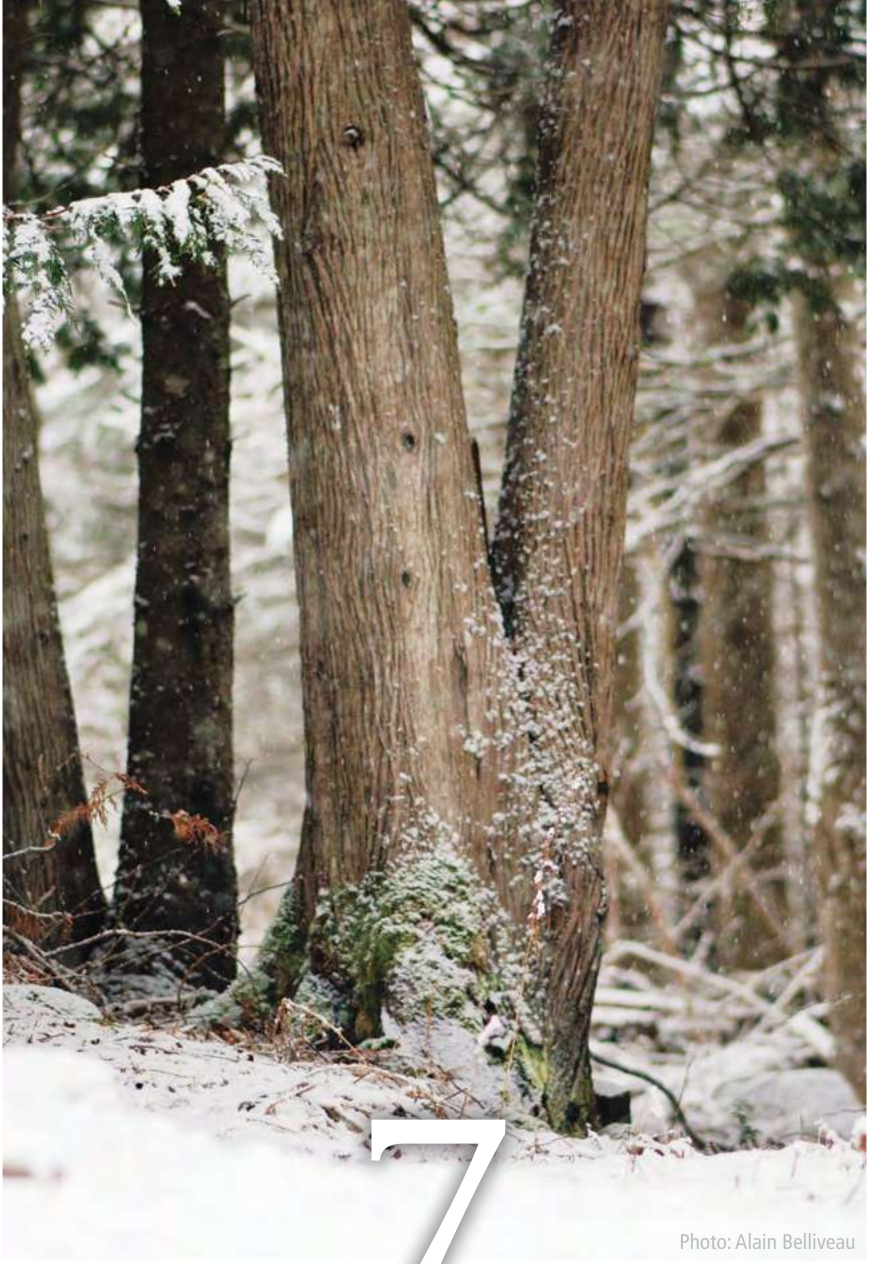


Photo: Alain Belliveau

7

CHAPTER

Restoring Forest Roads and Landings

Roads are considered one of the most detrimental disturbances to forests.[1] In addition to the direct habitat loss from their construction, roads act as conduits for invasive species and wildlife poaching, increase erosion and sedimentation of watercourses, fragment forest communities, and create an edge effect that many species of wildlife cannot withstand.[2] Although removal and restoration of roadbeds creates a short-term disturbance,[3] the overall effect is to defragment the landscape, restore hydrology, and improve wildlife habitat and biodiversity over time. The following prescriptions follow standard road removal methods.[4] Although much of this knowledge has been developed in the western United States,[5] the same principles apply to the New England–Acadian Forest region and can be implemented here.

The prescriptions for restoring forest roads and landings are very different from the silvicultural treatments described in Chapter 2. Road removal requires heavy equipment—often the same machines used to build the road—and is therefore quite intensive.

To ensure a successful project, a landowner must know how forest roads are removed in general, plus the site-specific resources and techniques required to do so. At minimum, the full extent of roads to be removed should be mapped, and detailed survey information collected (Table 4).

Table 4. Information required for road removal and roadbed restoration

Feature	Details
Access points	Location | Options for barriers
Road substrate, condition	Substrate type (hauled-in gravel, natural soil, etc.) | Washouts
Road dimensions	Total length and width | Steep slopes | Area of landings
Culverts and Bridges	Location, size, material and condition | Permits required?
Topsoil deposits	Location data for equipment operators
Boulders and large logs	Location data for equipment operators

Prescription 1: Blocking Road Access. At minimum, successful restoration requires that the road is no longer used. Blocking all access is the last step, since heavy equipment will need entry to the site. However, if there are multiple access points, blocking access to as many as possible will prevent the restored roadbeds from being compacted by intruders. Although gates and fencing are effective, a more natural approach—one that does not require maintenance of infrastructure—is to block access with large logs or boulders. Felling trees (preferably species from columns 4 and 5 of Table 1) over the restored road surface for a minimum distance of 100m (110 yards) from access points will also prevent traffic.

Prescription 2: Road and Ditch Ripping. The compacted soil on the road surface and adjacent ditches must be broken up to improve hydrology and soil aeration, and prepare a seedbed.[6] This is most effectively done using a bulldozer with a "ripper" or winged-subsoiler attachment. Alternatively, an experienced operator can use an excavator. All compacted soils (roadbed and ditches) should be ripped to a minimum depth of 50cm (20 inches), although ripping the entire depth of the compacted layer is preferred.

Prescription 3: Recontouring Road Segments and Slopes. This step involves spreading out the now-loosened soil and placing all fill material back from where it was removed during road construction. Fill should be sloped to the original contours of the site to promote overland dispersion of water. During this operation, organic material from ditches, embankments, and topsoil deposits should be mixed in with the redistributed fill. If sufficient organic material is available, placing a layer on top of the recontoured surface will promote the development of microsites for regeneration to establish. Placing large logs and boulders on the recontoured surface helps prevent erosion. If fill was brought in to build the original road surface, excess fill may need to be end-hauled off the site. Recontouring road segments is most effectively done with an excavator to strategically redistribute fill, mix fill with organic material, and move large logs and boulders.

Recontouring steep slopes is a major aspect of road removal projects in western North America. The restoration of steep slopes is complex and can be extremely dangerous. If this form of road restoration is required on your land, it should be planned and implemented by a forest engineer or equivalent practitioner. Do not attempt to recontour steep slopes without professional guidance.

Prescription 4: Restoring Watercourse Crossings. This involves removing all culverts, bridges, and other watercourse-crossing structures, then restoring the original stream channel contours. All fill material should be removed in and around watercourses; it can then be used in recontouring road segments (prescription 3). Remove fill down to the original stream channel but do not disturb the original channel bed. Depending on your jurisdiction, this type of work may require permits, which should be obtained before the project begins. Take every precaution to minimize erosion and sedimentation during the work. Any construction materials removed (culverts, bridge materials, etc.) should be end-hauled off the site.

Prescription 5: Planting. Planting the recontoured surface adds a level of complexity that may not be required for all projects. If a seed source is available on either side, the recontoured surface may revegetate naturally. It not, plant a variety of desirable species from Table 2 at a 2m-by-2m spacing, or 2,500 trees per hectare (6-by-6-foot spacing, or ~1,000 trees per acre). If landings or other openings are larger than $300m^2$ (328 square yards), plant a mix from Table 3. Additionally, in areas adjacent to restored watercourse channels, willows can be established to stabilize banks and discourage erosion and sedimentation (see Appendix D).

8

CHAPTER
Unique Situations

This chapter deals with the restoration of unique forest communities—those that are geographically distinct or restricted to a local setting. Generally, the restoration of these communities follows silviculture prescriptions similar to those for the scenarios described in Chapters 4–8 but with minor differences in how sites are prepared and the species mixes recommended for planting.

Unique Situation Scenarios

1a. Land adjacent to watercourses 10
1b. Land not adjacent to watercourses 11

2a. Land subject to annual or periodic flooding .... Floodplain Forest (pg. 62)
2b. Land not subject to annual or periodic flooding .... Riparian Forest (pg. 65)

3a. Land with saturated soils for most of the year .... Forested Wetland (pg. 66)
3b. Land that is rarely or never saturated 12

4a. Land in coastal ecoregions .... Coastal Forest (pg. 68)
4b. Land in the Appalachian Hardwood Zone .... Appalachian Hardwood Forest (pg. 67)

Floodplain Forest

Floodplain forests are among the most converted and least protected ecosystems in northeastern North America.[1] Their location on rich alluvial soils made them particularly vulnerable to conversion for agriculture and development, and the original extent of these forests has been greatly reduced. Floodplain forests are structurally complex and exceptionally biodiverse because of the seasonal interactions between terrestrial and aquatic processes.[2] For these reasons, restoring floodplain forests should be considered a high priority.

Most floodplain tree species that make up these communities are of conservation concern[3] and therefore warrant active restoration.[4] For example, White Elm and Butternut are susceptible to exotic diseases and have seen population declines throughout the region. Gene conservation programs for resistant strains of these species are under way.[5] If resistant stock becomes available, every effort should be made to restore these species across their natural range. Species such as Bur Oak and Black Willow are of concern because of their limited distribution in some areas of the region; they occur in disjunct populations that may be genetically distinct.[6] See Appendix E for species with restricted ranges within the region.

Floodplains can be grouped into two general categories—lower and upper. Lower floodplains flood annually and occur along large rivers and lakes. For more information on lower floodplain forest communities, see Silver Maple Floodplain Forest[7] in the Natural Landscapes of Maine.[8] Upper floodplains only flood occasionally and occur along small rivers or the upper reaches and terraces of large rivers. For more information on upper floodplain forest communities, see Upper Floodplain Hardwood Forest[9] in the Natural Landscapes of Maine,[10] and the Flood Plain Forest Group[11] in the Forest Ecosystem Classification for Nova Scotia.[12]

A wealth of literature addresses the restoration of floodplains, particularly in the lower Mississippi River valley,[13] and those concepts and treatments are also applicable to the New England–Acadian Forest region. Restoration often begins on abandoned agricultural land and therefore follows the prescriptions from Chapter 3, with the differences highlighted below. The tree species that inhabit floodplains differ greatly across the region, and so the species chosen for planting will ideally be informed by a reference community or historical records (see Chapter 2). Because such information may be unavailable, this manual divides the region into six distinct zones (Figure 3), based on their bottomland tree species compositions. These zones were determined using a variety of sources, including USDA range maps,[14] the Canadian Forest Service's *Trees in Canada*,[15] and Natureserve Ecological Communities.[16] The boundaries of these zones are not exact; use them as a guide rather than a rule. Table 5 provides a generalized upper and lower floodplain planting mix for each zone.

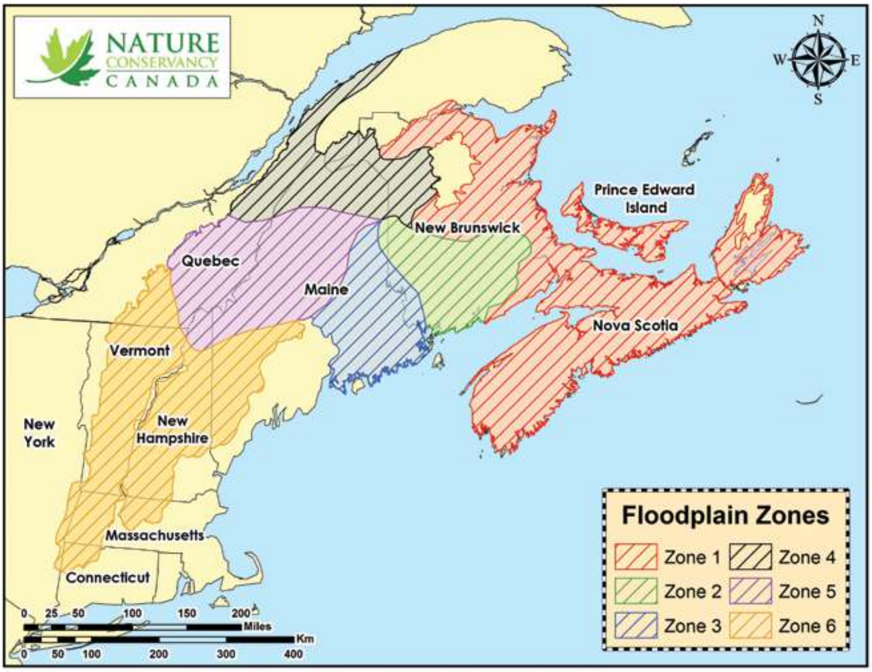


Figure 3. Floodplain Forest Zones in the New England - Acadian Forest region

Table 5. Tree species for planting upper and lower floodplains, by floodplain zone

	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Silver Maple	—	Lower	Lower	—	Lower	Lower
White Elm	Upper, Lower	Upper, Lower	Upper, Lower	Upper, Lower	Upper, Lower	Upper, Lower
Basswood	—	Upper, Lower	Upper, Lower	—	—	Upper, Lower
Red Ash	—	Upper, Lower	Upper, Lower	Upper, Lower	—	—
Butternut	—	Upper, Lower	—	—		Upper, Lower
Black Willow	—	Lower	—	—	—	Lower
Black Ash	—	Lower	Lower	Lower	Lower	Lower
White Ash	Upper, Lower	Upper	Upper	—	Upper	Upper
Red Oak	Upper, Lower	Upper	Upper	Upper	Upper	Upper
Sugar Maple	Upper, Lower	Upper	Upper	Upper	Upper	Upper
Ironwood	Upper, Lower	Upper	Upper	Upper	Upper	Upper
Red Maple	Upper, Lower	Upper	Upper	Upper, lower	Upper	Upper
Yellow Birch	Upper, Lower	Upper	Upper	Upper	Upper	Upper

Site Preparation

In some jurisdictions, site preparation may be restricted to activities that do not disturb soils on floodplains. In these cases, field vegetation should be mowed or bush-hogged repeatedly before planting. If no restrictions exist, plowing and disking the restoration site is highly recommended, except near banks that are susceptible to erosion or in swales that remain wet throughout the year; these areas can be mowed if required. In either case, prepare the site only after soils have had adequate time to dry in spring, and if soils are to be disturbed, plant directly afterward rather than waiting until the following spring. This limits soil loss during the flooding season.

Planting

Restoration of floodplain forests often begins with stabilizing the riverbanks on land that has been cleared to the waterline. Such land often suffers from scouring and erosion. Refer to Appendix D on establishing willows to restore and stabilize the banks of streams and rivers and thus minimize erosion. All other planting should follow the guidelines described in Chapter 3 using a mix of species that are native to your specific area (Table 5). Planting stock should be at least 30cm (12 inches) high, but 1m (3 feet) or taller is ideal on floodplains.[17]

Riparian Forest

For the purposes of this manual, riparian forests refer to lands within 30m (100 feet) of a watercourse that is not part of a floodplain. Riparian forests can occur in any of the scenarios described in Chapters 3–7 and should generally be treated similarly, with the differences highlighted below.

Photo: Alain Belliveau

Site Preparation

Depending on your jurisdiction, site preparation that disturbs soil may not be permitted in riparian zones. If restoring in an open field, vegetation should be mowed or bush-hogged repeatedly before planting. If no restrictions exist, plowing and disking is highly recommended, except near banks that are susceptible to erosion; these areas can be mowed if required. Naturally established shrubs along watercourses are important for preventing erosion and should not be removed during site preparation.

Planting

Restoration of riparian forests often begins with stabilizing streambanks if erosion is a concern. If stabilization is required, refer to Appendix D on how to establish willows. When planting trees, use the species mixes in Table 2, but if possible, include less common hardwoods, such as White Elm, Black Ash, and Ironwood. Planting stock should be at least 30cm (12 inches) high, but 50cm (20 inches) or more is ideal.[18]

Tending and Regenerating

Begin by determining what riparian buffer laws apply in your jurisdiction; there may be restrictions on removing trees within a watercourse buffer. Even if some harvesting is allowed, for restoration purposes, patch cuts should never be used within a riparian zone. Instead, use tending treatments such as crop-tree release, with or without spacing, to favour desirable species and create conditions for underplanting. Girdling should be the primary means of removing undesirable trees in riparian zones.

Forested Wetland

The general strategy of restoring forested wetlands is the same as for forested uplands, except for the recommended species for planting and restrictions on site preparation. Common forest communities on saturated soils include Black Spruce–Tamarack peatlands,[19] Red Maple swamps,[20] Black Ash swamps,[21] and Cedar swamps.[22] In many cases, forested wetlands in the New England–Acadian Forest were naturally colonized by boreal species, especially in organic, nutrient-poor, and nutrient-medium soils. Red Maple was also generally restricted to wet, swampy sites before land clearing that followed European settlement.[23] For more information on forested wetland communities, see the Wet Coniferous Forest Group[24] and Wet Deciduous Forest Group[25] in the Forest Ecosystem Classification for Nova Scotia.[26] Restoring forested wetlands generally follows the same treatment schedules outlined in the restoration scenarios of Chapters 3–7, including planting densities[27] and tending treatments, with the differences highlighted below.


Photo: Alain Belliveau

Site Preparation

No site preparation that will disturb wetland soils should be implemented in forested wetlands. If competing vegetation threatens planted trees, weed manually to minimize soil compaction and rutting.

Planting

When planting to restore forested wetlands, use the species mixes listed in Table 6.

Table 6. Suggested planting mixes for forested wetlands in the New England–Acadian Forest region

Soil nutrients	Species mix
Poor	Black Spruce | Tamarack
Medium	Balsam Fir | Red Maple | Black Ash
Rich	Eastern White Cedar | White Ash | Red Maple | White Elm | Black Ash

Appalachian Hardwood Forest

The Appalachian Hardwood Forest community occurs on nutrient-rich upland soils, often calcareous, and has a unique array of wildlife.[28] Its distribution is restricted to the south of the New England–Acadian Forest region, eastern Quebec, and a disjunct patch in the central St. John River valley (Figure 4).[29] In Canada, the extent of the Appalachian Hardwood Forest is thought to have declined to 0.8% or less of its original extent because of land clearing, making it a high priority for restoration.[30] In Maine, this forest type is often referred to as a "cove forest," and it is also considered a rare forest community.[31]

The primary indicator tree species are Basswood, Butternut, and Ironwood, intermixed in a typical tolerant-hardwood community of White Ash, Sugar Maple, and Yellow Birch.[32] Originally, conifer distribution in this area would likely have been patchy, such as in riparian zones and forested wetlands.[33]

Restoring the Appalachian Hardwood Forest follows the same treatments that apply elsewhere in the New England–Acadian Forest region (Chapters 3–7) but with different species. For the majority of woodlots in the Appalachian Hardwood Forest zone, restoration focuses on reestablishing tolerant hardwoods, with emphasis on the indicator tree species (Table 7). This may require establishing a nurse crop before planting tolerant hardwoods on abandoned farmland (see Appendix B). Butternut has been subject to exotic disease, and every effort should be made to restore this species if resistant stock is developed.

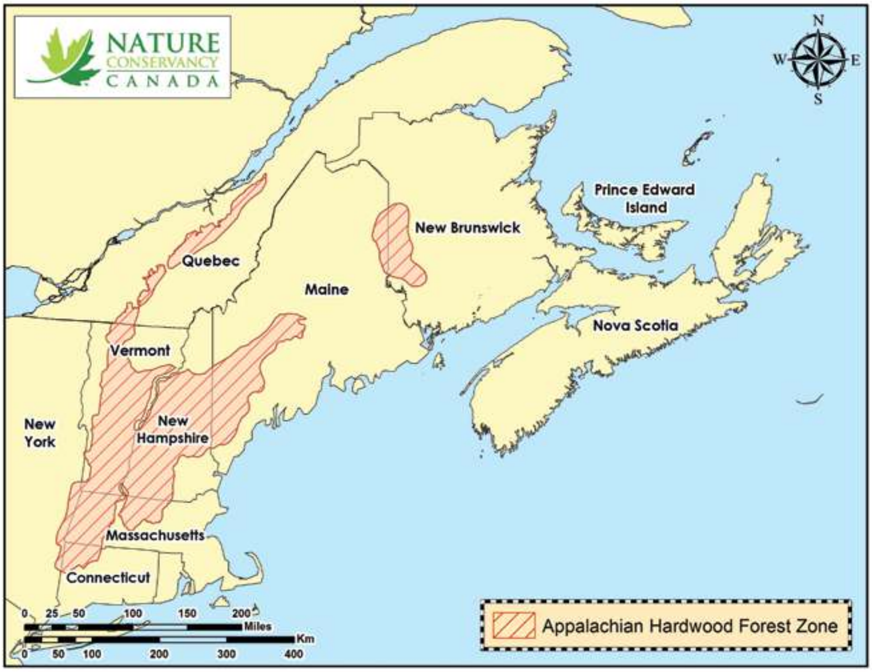


Figure 4. Appalachian Hardwood Zone in the New England–Acadian Forest region

Table 7. Suggested planting mixes for Appalachian hardwoods in the New England–Acadian Forest region

Soil moisture	Species mix
Moist	Butternut | Basswood | White Ash | Yellow Birch
Fresh	Butternut | Basswood | White Ash | Sugar Maple | Yellow Birch | Ironwood
Dry	Red Oak | Beech* | Sugar Maple | Yellow Birch | Ironwood

*See Appendix A for Beech management.

Coastal Forest

Coastal forest communities are often naturally composed of boreal tree species, which are better adapted to the exposed conditions that occur along the coast. For more information on these communities, refer to the Coastal Forest Group[34] in the Forest Ecosystem Classification for Nova Scotia,[35] and Maritime Spruce-Fir Forest[36] in the Natural Landscapes of Maine.[37]

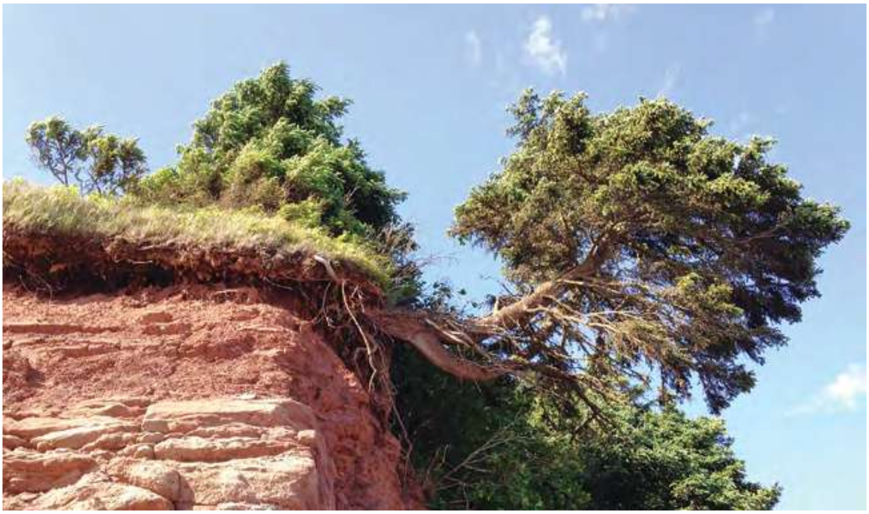
The general strategy of restoring coastal forests is the same as for other forest communities, with the exception of the species suggested for planting (Table 8). However, several coastal communities require special attention, as detailed below.

Table 8. Soil moisture and nutrient requirements for common coastal tree species in the New England–Acadian Forest region

Moisture Requirements	Nutrient Requirements: Poor	Nutrient Requirements: Medium	Nutrient Requirements: Rich
Wet	Black Spruce Tamarack	Tamarack Red Maple	Red Maple Eastern White Cedar
Moist	Black Spruce Balsam Fir	Red Spruce Balsam Fir White Birch Red Maple	Red Spruce Eastern White Cedar Red Maple
Fresh	Black Spruce White Spruce	Red Spruce Balsam Fir White Birch Red Maple	Red Spruce White Birch Red Maple Yellow Birch
Dry	Black Spruce	Red Spruce Balsam Fir White Birch	—

Coastal Headlands

If you are restoring cleared land that is directly adjacent to an exposed shoreline or coastal cliff, plant White Spruce in a 10m (30-foot) buffer at 3m-by-3m (10-by-10-foot) spacing —that is, in three rows. White Spruce can withstand harsh conditions that most other species cannot, such as salt spray and high winds. For more details on coastal White Spruce headlands, refer to CO2[38] in the Forest Ecosystem Classification for Nova Scotia.[39]



Coastal Red Spruce

Coastal Red Spruce is strongly associated with the Bay of Fundy and Gulf of Maine and should be favoured wherever possible for restoration of coastal forests. This includes underplanting in boreal communities that do not currently contain Red Spruce, as well as reestablishing Red Spruce on cleared lands. Although typically associated with Balsam Fir and White Birch, Yellow Birch can also be restored in these communities on rich, sheltered sites. For more details on coastal Red Spruce, refer to CO3[40] in the Forest Ecosystem Classification for Nova Scotia.[41]

Coastal Dune Forest

Several tree species are capable of colonizing coastal sand dunes, and their presence indicates the last stage in dune succession. In Nova Scotia and Prince Edward Island, White Spruce appears to be the only species that colonizes dunes. In New Brunswick, White Spruce, Tamarack, and Jack Pine have been observed growing on dunes. In southern Maine, Pitch Pine forms a natural dune community along the Atlantic Coastal Plain.[42] Collectively, these forests are rare and, like many coastal communities, have been degraded in some areas.

Restoration of dune forest should focus on planting White Spruce only, unless Tamarack, Jack Pine, or Pitch Pine are known to be part of the natural community in the restoration area. Do not attempt forest restoration on dunes unless (1) there is clear evidence (stumps, fire) that the dune was previously forested and then cleared, (2) dunes were planted with nonnative tree species (see Chapter 5), or (3) dune stabilization is needed to prevent coastal erosion. For more details on White Spruce dune forests, refer to CO7[43] in the Forest Ecosystem Classification for Nova Scotia.[44]

Coastal Red Oak

Coastal Red Oak forest is considered unique to Maritime Canada, and very little is known about its ecology. These communities appear to be restricted to the Northumberland Strait, particularly in New Brunswick and Prince Edward Island, although historically they likely occurred in Nova Scotia as well. Coastal Red Oak communities grow on the upland borders of salt marsh, and much of the original extent is assumed to have been destroyed by land clearing for agriculture and cottage development. Although dominated by Red Oak, this forest is commonly associated with Red Maple, and both species may grow in a stunted condition (presumably because of salt spray). Coastal Red Oak forests are rare and should be restored wherever Red Oak or Red Maple is found growing in proximity to salt marsh. To restore this community on abandoned agricultural lands, follow the prescriptions in Chapter 3. However, planting approximately 80% Red Oak and 20% Red Maple appears to match the natural composition of existing stands, and this is the suggested species mix for planting.

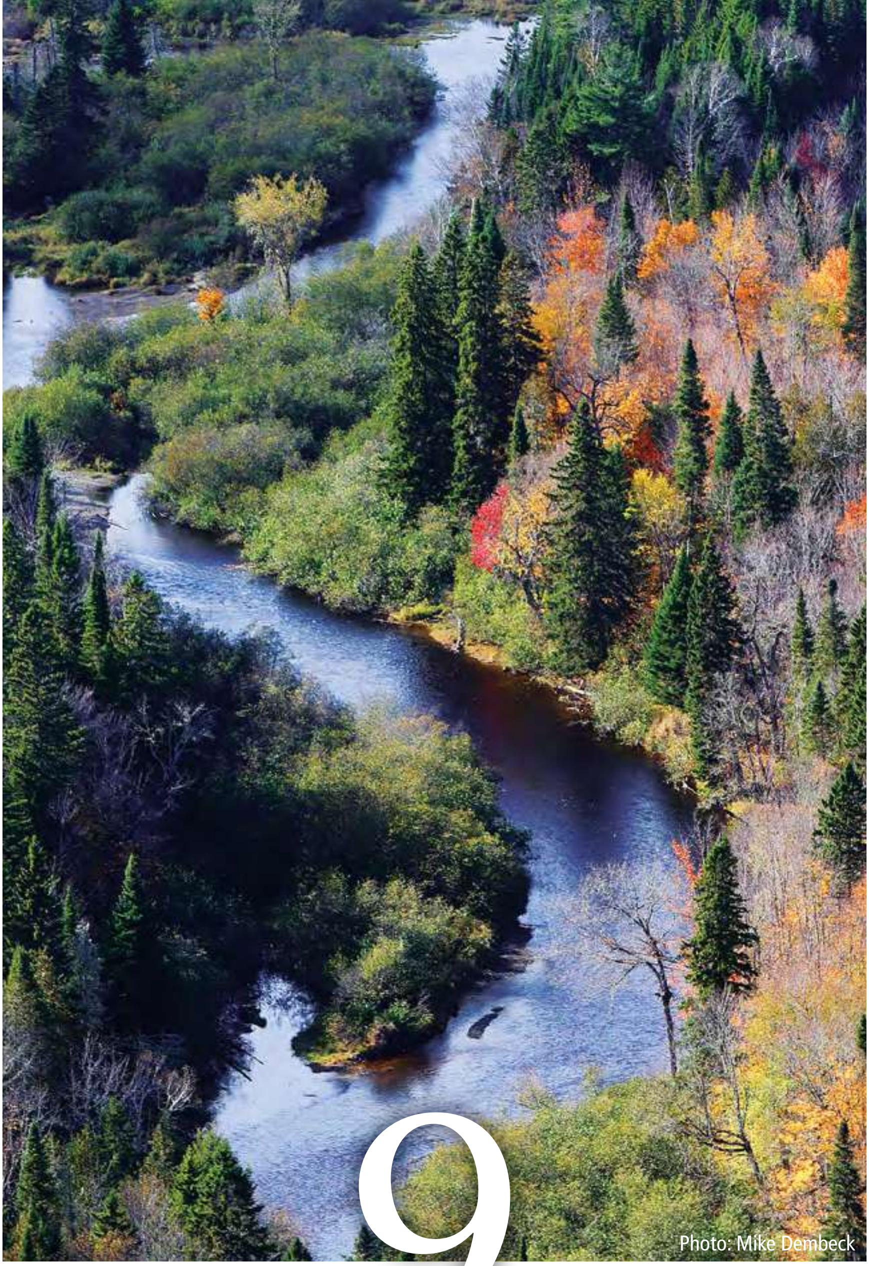


Photo: Mike Dembeck

9

CHAPTER

Moving Forward in New England–Acadian Forest Restoration

This chapter highlights areas of research and potential actions that would promote the restoration of New England–Acadian Forest. The list is not meant to be exhaustive or cover each subject in any detail. Instead, it is intended to bring attention to a few broad areas that could hasten the creation of an intact network of mature forest across the landscape.

Develop financial incentives for forest restoration. Cost is likely to be the number-one barrier to restoring New England–Acadian Forest. Implementing silvicultural treatments can be expensive, and programs that help offset these costs will likely result in broader uptake. Carbon markets, biodiversity offsets, and mitigation funding could all play a role in providing financial incentives to restore New England–Acadian Forest. The inclusion of restoration practices in provincial and state silviculture funding programs could also promote restoration activities.

Establish guidelines for restoring plant communities. Although the restoration of forest understorey shrub and herb communities is beyond the scope of this manual, they are critical parts of forest biodiversity and integral to forest structural complexity. In many cases, shrubs and herbs naturally colonize restored areas, but this is not always the case, and a better understanding of the habitat requirements of forest shrubs and herbs could greatly enhance restoration projects. Further research into the shrubs and herbs best suited for restoration, their soil nutrient and moisture requirements, and how to propagate them is highly recommended. Restoring rare or endangered species, as has been done elsewhere, deserves particular attention.[1]

Develop a network of tree nurseries across the region. Compared with commercial nurseries producing trees in large quantities, small private nurseries often have more flexibility to grow a wider selection of species to meet landowners' needs. Each primary watershed in the region should have at least one nursery that specializes in native trees. Alternatively, a few large nurseries might specialize in native tree stock for each primary watershed. In both situations, the aim is to promote the conservation of genetic diversity of native tree species, and eventually shrubs and herbaceous plants as well.

Develop a New England–Acadian Forest restoration practitioner network. An online, peer network of restoration practitioners would allow land trusts, protected area managers, and woodlot owners to share techniques, provide advice, and document their successes and failures. The primary goal of the network would be to create a community of restoration specialists, with a secondary goal of maintaining a database of restoration projects that can be monitored over the long term.

Develop a New England–Acadian Forest restoration research network. Despite the wealth of literature on commercial silviculture practices pertaining to the region, very little research has focused on restoring these communities

for biodiversity. The need to develop this research agenda is obvious. A forest restoration research network would strengthen the science of New England–Acadian Forest restoration to promote native biodiversity by addressing the following topics, among others:

- the ecology of poorly understood forest communities;
- nursery propagation and habitat requirements of native tree, shrub, and herb species;
- indicators to judge the success of restoration over sequential time periods;
- advancing silvicultural systems that aim to conserve biodiversity[2];
- using nurse crops for restoration (see Appendix B for more detail).

Strengthen the connection between New England–Acadian Forest restoration and climate change adaptation. Generally, the restoration scenarios described in this manual can be considered synonymous with managing forests for climate change. Boreal species are largely expected to decline, whereas temperate species are expected to benefit from warming temperatures (all else held equal)[3]. Promoting long-lived, shade-tolerant, temperate forest communities will enhance resilience to climate change in the region. Since many current industrial practices directly or indirectly favour boreal tree species that are likely to decline with further climate change, restoration of the New England-Acadian Forest has an economic rationale as well. Public understanding of the need for climate change adaptation will, we hope, generate the political will for large-scale investment in forest restoration.


Photo: Alain Belliveau

Appendix A
Beech Management

Throughout the region, Beech is susceptible to a fatal invasive disease called Beech bark disease.[1] As a result, Beech is considered a species of concern in some jurisdictions.[2] However, genetically resistant Beech are known to occur throughout the region, albeit in relatively low numbers (approximately 3% of trees).[3] It is now known that both breeding and silviculture can favour these disease-resistant, "clean" Beech,[4] which are an integral part of the New England–Acadian Forest.

Silviculture prescriptions to manage Beech for restoration aim to accomplish two things: (1) increase the proportion of clean Beech wherever possible, and (2) control diseased Beech regeneration, particularly those that originate from root suckering. Increasing the proportion of clean Beech involves protecting and regenerating any naturally occurring healthy trees, and planting genetically resistant stock where it does not occur.[5] Controlling Beech regeneration originating from root suckers, particularly from diseased parent stock, is also an important consideration because root suckers often grow into thickets that hinder the regeneration of other species.[6]

To manage Beech when implementing silviculture prescriptions for restoration, follow these guidelines:

- Any Beech tree that does not show evidence of disease should be treated as a crop tree, regardless of size, and left uncut.
- Where clean and diseased Beech co-occur, selectively remove the unhealthy trees in both patch cuts and tending treatments.[7] Selective removal has been shown to effectively increase the proportion of clean Beech over time.[8]
- When creating patches in areas with diseased Beech, avoid disturbing the ground to limit root suckering.[9] Injury to roots during harvesting appears to be a prerequisite to root suckering.[10]
- In areas containing Beech root-sucker thickets (as is common in high-grades), remove the majority of suckers within patches to allow other species to colonize.[11] Use the patch equation from Chapter 3.
- Girdling should be the primary means of removing both diseased mature trees and, where possible, root suckers. This method has been shown to be effective even on small-diameter stems,[12] and unlike cutting, girdling discourages stump sprouting and further root suckering.
- If genetically resistant Beech planting stock, the subject of current research,[13] becomes commercially available, it should be planted to restore Beech throughout it's historic range.

Appendix B

Establishing Nurse Crops for Restoration

For restoration purposes, a nurse crop is defined as trees or shrubs, either naturally occurring or planted, used to improve the survival of young trees of a more desirable species. Nurse crops may provide shade, protect against frost and wind, add nutrients to the soil, modify the microclimate, or improve the understorey composition, among other benefits.[1] The potential advantage of establishing nurse crops is that a wider array of desirable species might be planted earlier than without a nurse crop, ultimately hastening the overall restoration toward mature New England–Acadian Forest. Despite considerable research on using nurse crops to maximize biomass potential on abandoned agricultural land, very little information exists on establishing nurse crops specifically for forest restoration and biodiversity.

This appendix introduces the concept of nurse crops for restoring New England–Acadian Forest biodiversity and explains how landowners can test two approaches that appear to be relevant to restoration in the region: establishing intolerant hardwoods and using alder.

Intolerant Hardwoods

Establishing fast-growing intolerant hardwoods as a nurse crop on abandoned agricultural land or in high-grades may aid restoration because these trees (1) rapidly develop structural diversity, (2) naturally control weedy vegetation, and (3) create an understorey environment that is suitable for desirable species, among other reasons.[2] Drawn from studies in both Europe and the United States,[3] the following method is suggested for establishing a nurse crop of intolerant hardwoods when restoring forest on abandoned agricultural land (but not floodplains):

1. The recommended species for planting is Balsam Poplar, which grows fast, survives within a range of conditions, and can be planted from unrooted cuttings.[4] Alternatively, rooted aspen (Trembling or Large-Tooth) or White Birch could be used for trial purposes.
2. Intolerant hardwoods should be widely spaced. The recommended spacing is 4m by 4m, or 625 stems per hectare (13 by 13 feet, or ~250 stems per acre).[5]
3. In old fields, competing vegetation between nurse trees must be controlled until canopy closure occurs.
4. After two or more growing seasons, interplant desirable species from Table 2 between nurse trees to achieve an overall stem density of 2,500 stems per ha, with 2m-by-2m spacing (~1,000 stems per acre, with 6-by-6-foot spacing).
5. Once desirable species are established, treatments can follow those in the Old-Field Borealized Hardwood scenario (Chapter 3), starting at prescription 4.

Alder

Alders are often regarded as a pest, but they may be a natural nurse crop for restoring New England–Acadian Forest. Not only should alder be favoured over boreal conifers in old fields, there may even be a benefit to planting old fields with alder. Preliminary evidence indicates that planted oak and ash species survive better among old-field alders than in forested or open field settings, even when herbicide treatments were applied to the latter two.[6] Further research is warranted to determine how tree species listed in Table 2 respond to being planted among old-field alders. Generally, alder may be a good nurse crop because it (1) grows rapidly to form a low canopy with dappled shade, (2) can establish across a wide range of soil conditions, (3) decomposes rapidly, increasing soil organic matter, and (4) fixes atmospheric nitrogen into the soil.[7] Alders have been shown to add up to 160 kg/ha (140 lbs/acre) of nitrogen to soil annually[8].

The following method for collecting, growing, and outplanting alder as a nurse crop when restoring New England–Acadian Forest on abandoned agricultural land is adapted from the *Native Plant Revegetation Manual for Denali National Park and Preserve*[9]; the park saw a 95% survival rate after five years and heights of 1m to 3m (3 to 10 feet).

1. The recommended species to establish is Speckled Alder (also called Red Alder); it is native to the region and can grow across a range of conditions, including old fields.[10]
2. Collect alder seeds in late fall. Also collect alder root nodules during this time to inoculate nursery soil with nitrogen-fixing bacteria.
3. Germinate and grow seeds for at least three months in a greenhouse setting. Seedlings are best grown as container stock and require fertilizer or compost.
4. Outplanted alders should be widely spaced. The recommended spacing is 4m by 4m (13 by 13 feet). Add fertilizer or compost to the planting holes.
5. Control competing vegetation between alders until canopy closure occurs.
6. After two or more growing seasons, interplant desirable species from Table 2 between alder clumps to achieve an overall stem density of 2,500 stems per hectare, or 2m-by-2m spacing (~1,000 stems per acre, or 6-by-6-foot spacing).
7. Once desirable species are established, follow the treatments in the High Shrubland scenario (Chapter 3), starting at prescription 3.

Appendix C

Soil Moisture and Nutrient Assessment Guidelines

Table C1. Soil moisture class definitions[1]

Moisture class	General definition
Wet	Soils are saturated for most of the growing season. Moisture comes from permanent seepage or permanently high water table.
Moist	Soils are wet for more than half of the growing season but have extended dry periods. Soil moisture mostly reflects seepage and, to a lesser extent, precipitation.
Fresh	Soils are dry for more than half of the growing season but have extended moist periods. Soil moisture often reflects precipitation.
Dry	Soils drain rapidly and are dry for most of the growing season. Soil moisture almost entirely reflects recent precipitation.

Table C2. Soil nutrient class definitions[2]

Nutrient class	General Definition
Poor	Soils are often shallow, acidic, and coarse textured. Surface organic matter is usually thick because of slow decomposition. Soil water content, if any, is usually stagnant.
Medium	Soils are of moderate depth and medium textured. Soil water content, if any, is usually flowing rather than stagnant.
Rich	Soils are often deep and medium or fine textured. Surface organic matter is usually thin from rapid decomposition. Soil water content is usually flowing rather than stagnant.

Table C3. Common indicator plant species for determining soil moisture and nutrient classes[3]

Moisture Requirements	Nutrient Requirements: Poor	Medium	Rich
Wet	Bog Rosemary Leatherleaf Goldthread Mayflower Labrador Tea Mountain Holly	Speckled Alder Red Osier Dogwood Goldthread Mountain Holly	Dwarf Raspberry Stinging Nettle Sensitive Fern
Moist	Mayflower Labrador Tea, Goldthread Mountain Holly	Speckled Alder Red Osier Dogwood Sarsaparilla Goldthread Mountain Holly Wood Sorrel	Dwarf Raspberry Canada Yew Sarsaparilla Stinging Nettle Wood Sorrel
Fresh	Mayflower Pink Lady's Slipper Green Alder	Pin Cherry Sarsaparilla Fireweed Wood Sorrel	Beaked Hazel Dwarf Raspberry Canada Yew Sarsaparilla Baneberry Wood Sorrel
Dry	Prince's Pine Sweet Fern Mayflower Common Juniper Pink Lady's Slipper Green Alder	Common Juniper Pin Cherry Fireweed	—

Appendix D

Willow Planting Guidelines for Stream and Riverbank Stabilization

Where land is cleared up to the edges of rivers and streams, banks may be unstable, resulting in erosion and sedimentation. In many restoration scenarios, stabilizing these banks is the first priority to prevent loss of soil and protect planted trees from erosion. The following treatment schedule establishes willow to stabilize streams and riverbanks.

Prescription 1: Mowing. The recommended method to prepare a site for willow plantings is mowing. Herbaceous field vegetation should be mowed in the autumn before planting. This will allow for planting early in the spring when the soil is saturated, giving the willows a full growing season to develop their root systems. Although activities that disturb the soil directly adjacent to rivers and streams are generally not recommended, if banks are sloughing from erosion, they may need to be graded to a shallower slope. The ideal slope for planting willow is less than 2:1 (Figure D1),[1] but the final grade will depend on the extent of erosion and whether you are legally able to grade riparian soils in your jurisdiction. Whether grading is done by hand or with machinery, ensure that proper silt fencing is installed to prevent sedimentation of the watercourse.

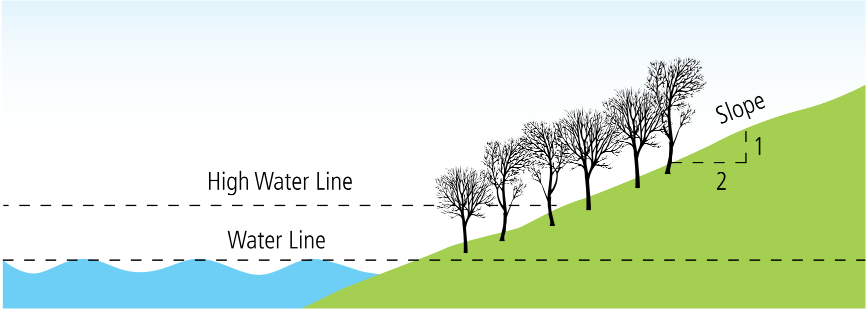


Figure D1. Suggested slope for willow planting. Produced under Licence with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2017.

Prescription 2: Planting. Although a variety of willow species can be used, two species of willow are especially recommended for planting: Red-Tipped Willow, and Pussy Willow, both of which grow vigorously and are native throughout the region. Willow cuttings should be collected when they are dormant,[2] so harvest them in late autumn, winter, or very early spring. Cuttings should be a minimum of 2cm (3/4 inch) wide at the base; large cuttings tend to work better than small ones.[3] Cuttings should be as long as possible when harvested and can be cut to length when planted. Trim all twigs and branches and remove several inches from the top of the stem[4] to redirect energy to root development when the cutting is planted. Cut the base of the stems at a 45° angle and mark the bottoms to ensure cuttings are not planted upside-down. They can be bundled for transport and stored in plastic in a dark, moist, cold environment, such as a snowbank.[5]

Willows can be planted as soon as the ground has thawed in the spring.[6] Since the water will be high, you may need to make multiple plantings down to the low-water line. Plant in a zig-zag fashion, with stems approximately 1m (3 feet) apart (Figure D2).[7] On high, eroded slopes, use a denser spacing, 50cm by 50cm (20 by 20 inches), and insert stems both vertically and diagonally into the soil.[8] Plant a minimum of three rows; five or more may be required on sites that experience heavy erosion.

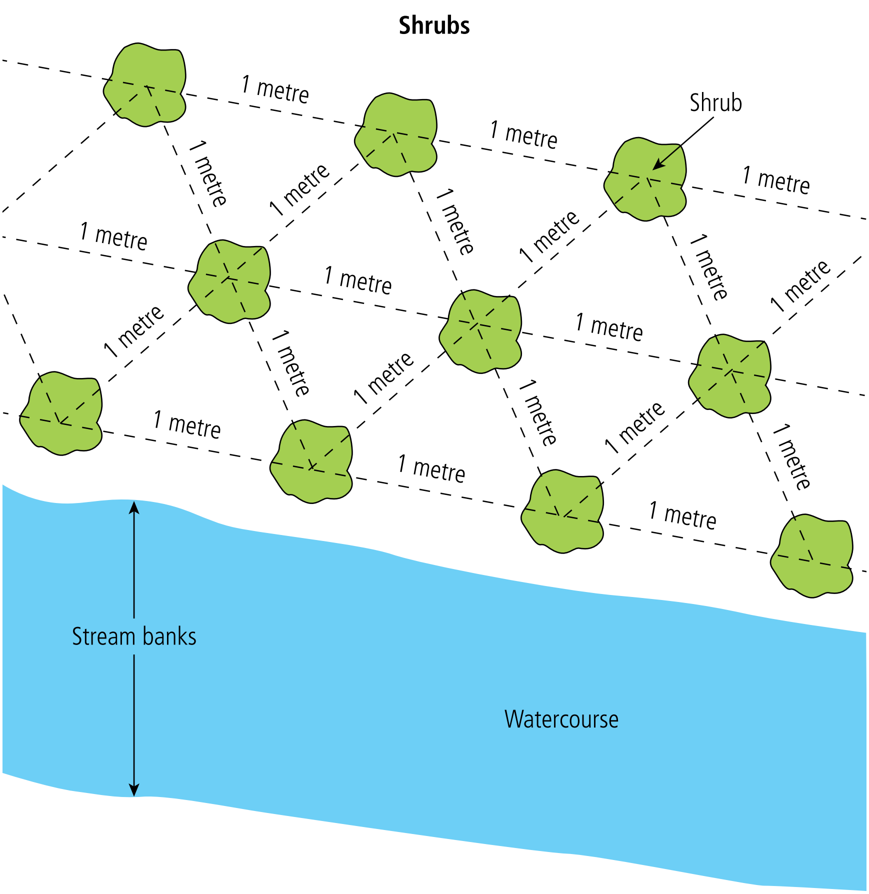


Figure D2. Suggested willow-planting design, adapted from Bastien-Daigle.[9]
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Cuttings can be cut to length as needed but should be at least 60cm (24 inches) long.[10] Cut them at an angle so that they can be pushed into the soil by hand (wear heavy gloves), or hammer the stems into the ground using a mallet. On dry soils, willows should be planted to the low-water level to ensure adequate moisture.[11] On high, eroded banks, use longer stems; a piece of rebar can be used as a dibble to create pilot holes.[12] Regardless of size, all cuttings should be buried at least three-quarters of their length.[13] Once they have been inserted into the ground, tamp the soil around them, since air pockets can kill the new roots.

Prescription 3: Pruning. After the stems have hardened off in autumn, prune one-third to one-half of the planted cuttings back to 5cm (20 inches) above the ground. This step is recommended to encourage coppicing and root growth the following spring.[14] Any cut stems larger than 2cm (3/4 inch) at the base can be used for other stabilization projects.

Appendix E
Nomenclature

Table E1. Common and scientific names of species

	Common name	Scientific name
Trees	Balsam Fir	*Abies balsamea*
	Balsam Poplar	*Populus balsamifera*
	Basswood	*Tilia americana*
	Beech	*Fagus grandifolia*
	Black Spruce	*Picea mariana*
	Black Willow	*Salix nigra*
	Bur Oak	*Quercus macrocarpa*
	Butternut	*Juglans cinerea*
	Eastern Hemlock	*Tsuga canadensis*
	Eastern White Cedar	*Thuja occidentalis*
	Eastern White Pine	*Pinus strobus*
	European Larch	*Larix decidua*
	Ironwood	*Ostrya virginiana*
	Jack Pine	*Pinus banksiana*
	Japanese Larch	*Larix kaempferi*
	Large-Tooth Aspen	*Populus grandidentata*
	Norway Maple	*Acer platanoides*
	Norway Spruce	*Picea abies*
	Pitch Pine	*Pinus rigida*
	Red Ash	*Fraxinus pennsylvanica*
	Red Maple	*Acer rubrum*
	Red Oak	*Quercus rubra*
	Red Pine	*Pinus resinosa*
	Red Spruce	*Picea rubens*
	Scots Pine	*Pinus sylvestris*
	Silver Maple	*Acer saccharinum*
	Sugar Maple	*Acer saccharum*
	Tamarack	*Larix laricina*

	Common name	Scientific name
Trees	Trembling Aspen	*Populus tremuloides*
	White Ash	*Fraxinus americana*
	White Birch	*Betula papyrifera*
	White Elm	*Ulmus americana*
	White Spruce	*Picea glauca*
	Yellow Birch	*Betula alleghaniensis*
Shrubs, small trees	Canada Yew	*Taxus canadensis*
	Dwarf Raspberry	*Rubus pubescens*
	Glossy Buckthorn	*Frangula alnus*
	Green Alder	*Alnus crispa*
	Grey Birch	*Betula populifolia*
	Common Juniper	*Juniperus communis*
	Labrador Tea	*Rhododendron groenlandicum*
	Leatherleaf	*Chamaedaphne calyculata*
	Mountain Ash	*Sorbus americana*
	Mountain Holly	*Ilex mucronata*
	Pin Cherry	*Prunus pensylvanica*
	Pussy Willow	*Salix discolor*
	Red-Osier Dogwood	*Cornus sericea*
	Red-Tipped Willow	*Salix eriocephala*
	Speckled Alder	*Alnus incana*
	Striped Maple	*Acer pensylvanicum*
	Witch Hazel	*Hamamelis virginiana*
Herbaceous plants	Fireweed	*Chamerion angustifolium*
	Goldthread	*Coptis trifolia*
	Hardhack	*Spiraea tomentosa*
	Mayflower	*Epigaea repens*
	Meadowsweet	*Spiraea alba*
	Pink Lady's Slipper	*Cypripedium acaule*
	Prince's Pine	*Chimaphila umbellata*
	Sarsaparilla	*Aralia nudicaulis*
	Sensitive Fern	*Onoclea sensibilis*
	Stinging Nettle	*Urtica dioica*
	Sweet Fern	*Comptonia peregrina*
	Wood Sorrel	*Oxalis montana*

Appendix F

Tree Species with Southern Affinities

This appendix describes habitat preferences for 20 tree species that are rare or uncommon in the New England–Acadian Forest. These trees have a southern affinity more indicative of the northeastern coastal plain[1] and other ecoregions to the south. However, many of the species have ranges that overlap the southern boundary of the New England–Acadian Forest region, or include disjunct populations in the region's interior. They are highlighted here to bring attention to their importance to the region's overall biodiversity and to promote their conservation and restoration if found.

American Chestnut (*Castanea dentata*). American Chestnut, once the dominant species of eastern forests, has been largely extirpated by an exotic fungal disease.[2] The original native range included southern New England, extending into southern New Hampshire and Vermont, with at least one disjunct population in southern Maine.[3] American Chestnut grew in a variety of soil conditions, both in pure stands and mixed with other tolerant hardwoods. This species is of conservation concern throughout its range and if found, should be protected and reported to your state conservation department. Because of ongoing research, resistant strains of American Chestnut may be available for restoration purposes in the near future.[4] If resistant stock becomes commercially available, this species should be restored throughout its range.

American Hornbeam (*Carpinus caroliniana*). American Hornbeam, or "Blue-Beech," grows throughout southern New England but also appears in most of Vermont and extends along the coastal plain of New Hampshire and Maine.[5] It prefers upper floodplains, swamps, and riparian soils but can grow across a variety of soil conditions. Although very shade tolerant, it is typically only a minor component of hardwood forests in the New England–Acadian Forest region.[6] American Hornbeam should therefore be conserved wherever it is naturally found and can be restored by underplanting in hardwood stands.

American Sycamore (*Platanus occidentalis*). American Sycamore is native within the southern limit of the New England–Acadian Forest region. Historically, it extended into New Hampshire, Vermont, and Maine, with disjunct populations in the latter two states.[7] The Maine population may now be extirpated,[8] so it is a priority for conservation and restoration. This species prefers the moist soils of upper floodplains, swamps, and riparian areas and is most commonly found growing with Red Maple, White Elm, and Black Ash in the region.[9] Because it is also known to occasionally colonize old fields, it may make a valuable addition to old-field restoration within its natural range.

Atlantic White-Cedar (*Chamaecyparis thyoides*). In the New England–Acadian Forest region, Atlantic White-Cedar occurs in a single disjunct population in southern New Hampshire. Outside the region, it grows along the coastal plain of New England.[10] This species is relatively intolerant of shade and prefers wet, organic soils, such as those found in swamps and bogs.[11] Overexploitation—it was prized for its light, decay-resistant wood—has made it one of the rarest forest communities in the eastern United States.[12] Atlantic White-Cedar should be strictly protected wherever it is found. This species is a priority candidate for restoration across its natural range.

Bitternut Hickory (*Carya cordiformis*). Bitternut Hickory grows throughout southern New England and extends into southern Vermont, New Hampshire, and Maine.[13] This species prefers moist soils along floodplains and riparian areas but will grow in rich upland soils as well. In the New England–Acadian Forest region, it is typically mixed with other tolerant hardwoods, such as Red Oak, Sugar Maple, and Basswood.[14] Bitternut Hickory is rare in Maine,[15] and because of its limited distribution in the region, it should be preserved and encouraged wherever it is naturally found.

Black Maple (*Acer nigrum*). In the New England–Acadian Forest region, Black Maple can be found in three small, disjunct populations—one each in Connecticut, Massachusetts, and New Hampshire.[16] In these areas, Black Maple is commonly mixed with other shade-tolerant hardwood species that prefer rich soils, such as Sugar Maple, Basswood, and White Ash.[17] This species is both closely related to and commonly associated with Sugar Maple, and as such has been treated by some as a subspecies of Sugar Maple.[18] Regardless, the genetic distinction of Black Maple makes it an important conservation priority across its range. It can be restored similarly to Sugar Maple.

Black Oak (*Quercus velutina*). Black Oak grows throughout southern New England and extends into southern Vermont, New Hampshire, and Maine.[19] It tends to grow in dry uplands and is commonly associated with White Pine or with tolerant hardwoods, such as Sugar Maple and White Ash. In Maine, communities that support Black Oak are rare and include Oak-Hickory Forest, in which other uncommon oak species and Shagbark Hickory can be found.[20] Black Oak can tolerate only moderate shade and therefore can be restored similarly to Red Oak within its natural range.

Black Tupelo (*Nyssa sylvatica*). Black Tupelo, commonly known as Blackgum, grows throughout southern New England and extends into southern Vermont, New Hampshire, and Maine, with a single disjunct population in northern Vermont.[21] In the New England–Acadian Forest region, Black Tupelo is commonly associated with Black Ash, Red Maple, and White Elm in swamps or upper floodplains.[22] This species is quite tolerant of shade, making it a good candidate for underplanting when restoring forested wetlands and floodplains.

Bur Oak (*Quercus macrocarpa*). Bur Oak is typically associated with central North America but does occur in the New England–Acadian Forest region in three disjunct populations: (1) the Connecticut-Massachusetts border area, (2) south-central Maine, and (3) the lower St. John River valley of New Brunswick.[23] In the region, Bur Oak is most commonly found on floodplain soils and is often associated with Silver Maple, White Elm, Basswood, and other bottomland species.[24] Because of its limited distribution and the historical loss of habitat from land clearing on floodplains, Bur Oak should be protected and restored wherever it occurs.

Chestnut Oak (*Quercus prinus*). Chestnut Oak occurs along the far southern boundary of the New England–Acadian Forest region, but western Maine has a single disjunct population.[25] This species is typically found on dry uplands with Eastern White Pine, Red Maple, and Red Oak and may occur with other uncommon species in the region, such as Shagbark Hickory and White Oak.[26] Its rarity suggests that this species should be conserved wherever it is found. Because of its affinity for dry, shallow soils and its intermediate shade tolerance, Chestnut Oak may be a good candidate for restoration on nutrient-depleted soils within its natural range.

Eastern Redcedar (*Juniperus virginiana*). Eastern Redcedar grows throughout southern New England and extends into southern Vermont, New Hampshire, and Maine.[27] It is very intolerant of shade but can grow across a wide range of soil conditions, from dry rocky ridges to swamps.[28] Eastern Redcedar is also known to readily colonize abandoned farmland and is associated with many other tree species in natural forest communities.[29] For these reasons, Eastern Redcedar may be a prime candidate as a nurse crop for restoring abandoned farmland across its range.

Hackberry (*Celtis occidentalis*). Hackberry is found only in the extreme south of the New England–Acadian Forest region[30] and is typically associated with floodplain tree species such as White Elm, Red Ash and Basswood.[31] Because of its restricted distribution in the region, this species should be conserved wherever found and can be included in a planting mix with other floodplain tree species for restoration within its natural range.

Pignut Hickory (*Carya glabra*). Pignut Hickory is found in the extreme south of the New England–Acadian Forest region, but central New Hampshire has a single disjunct population.[32] This species grows on both moist and dry soils and is commonly associated with Red Maple, White Pine, and Red Oak.[33] It may also be found with other uncommon oak species on dry sites, such as Chestnut Oak.[34] This species should be conserved wherever it is found and could be restored within its natural range by planting with other dry-site affiliated species.

Red Elm (*Ulmus rubra*). Red Elm (or Slippery Elm) occurs throughout most of southern New England and New Hampshire but also in Maine as three small, disjunct populations.[35] It prefers floodplain soils and is commonly associated with Silver Maple, White Elm, Red Maple, and other floodplain species.[36] As with White Elm, Dutch elm disease and habitat loss have caused declines of Red Elm in natural floodplain communities. For this reason, the species should be conserved where found, particular if it appears resistant to Dutch elm disease. If resistant stock becomes available, this species can be restored on floodplains across its range.

Sassafras (*Sassafras albidum*). Sassafras occurs along the extreme southern boundary of the New England–Acadian Forest region and in two disjunct populations, one each in central New Hampshire and western Maine.[37] This species is intolerant of shade, grows in a wide variety of soils, is associated with many different tree species, and will readily colonize abandoned farmland. For these reasons, Sassafras may be a good candidate as a nurse crop for restoring abandoned farmland[38] within its natural range.

Scarlet Oak (*Quercus coccinea*). Scarlet Oak occurs throughout southern New England, up through central New Hampshire and into southern Maine.[39] This species tends to grow in dry upland soils but can occur across a range of soil conditions. In the New England–Acadian Forest region, Scarlet Oak is associated with White Pine, Red Oak, and other oaks with southern affinities.[40] It can be restored similarly to other dry site–adapted species across its natural range.

Shagbark Hickory (*Carya ovata*). Shagbark Hickory grows throughout southern New England and extends into southern Vermont, New Hampshire, and Maine.[41] In the New England–Acadian Forest region, this species grows in uplands and is most commonly associated with Eastern White Pine, oaks with southern affinities, and tolerant hardwoods, such as Sugar Maple and White Ash.[42] Because of its limited distribution in the region, Shagbark Hickory should be encouraged wherever it is naturally found. It can be restored along with White Pine and other upland hardwood species within its natural range.

Swamp White Oak (*Quercus bicolor*). Swamp White Oak occurs in the extreme south of the New England–Acadian Forest region, as well as in two disjunct populations in southern Maine.[43] This species grows in swamps, floodplains, and riparian areas and is commonly associated with other hardwoods that prefer wet soils, including Silver Maple, White Elm, Red Ash, Black Willow, and Basswood.[44] Because it is a threatened species in Maine[45] and has a very limited distribution elsewhere in the region, Swamp White Oak should be protected and restored wherever it naturally occurs.

Tuliptree (*Liriodendron tulipifera*). Tuliptree occurs in the extreme south of the New England–Acadian Forest region, as well as in a disjunct population in central New Hampshire.[46] Tuliptree grows in a variety of soil conditions, but in the region, it is most often found on soils that support other tolerant hardwoods, such as Beech, Sugar Maple, and White Ash.[47] Because of its restricted range in the region, Tuliptree should be conserved wherever it is found; it can be restored alongside other tolerant hardwood species.

White Oak (*Quercus alba*). White Oak grows throughout southern New England and extends into southern Vermont, New Hampshire, and Maine.[48] It grows across a wide range of soils and may be part of a variety of forest communities, including early-successional hardwoods, Sugar Maple, Eastern Hemlock, and Pine-Oak communities.[49] White Oak can be restored in all of these communities and may be particularly well suited for restoration in clearcuts and high-grades throughout its natural range.

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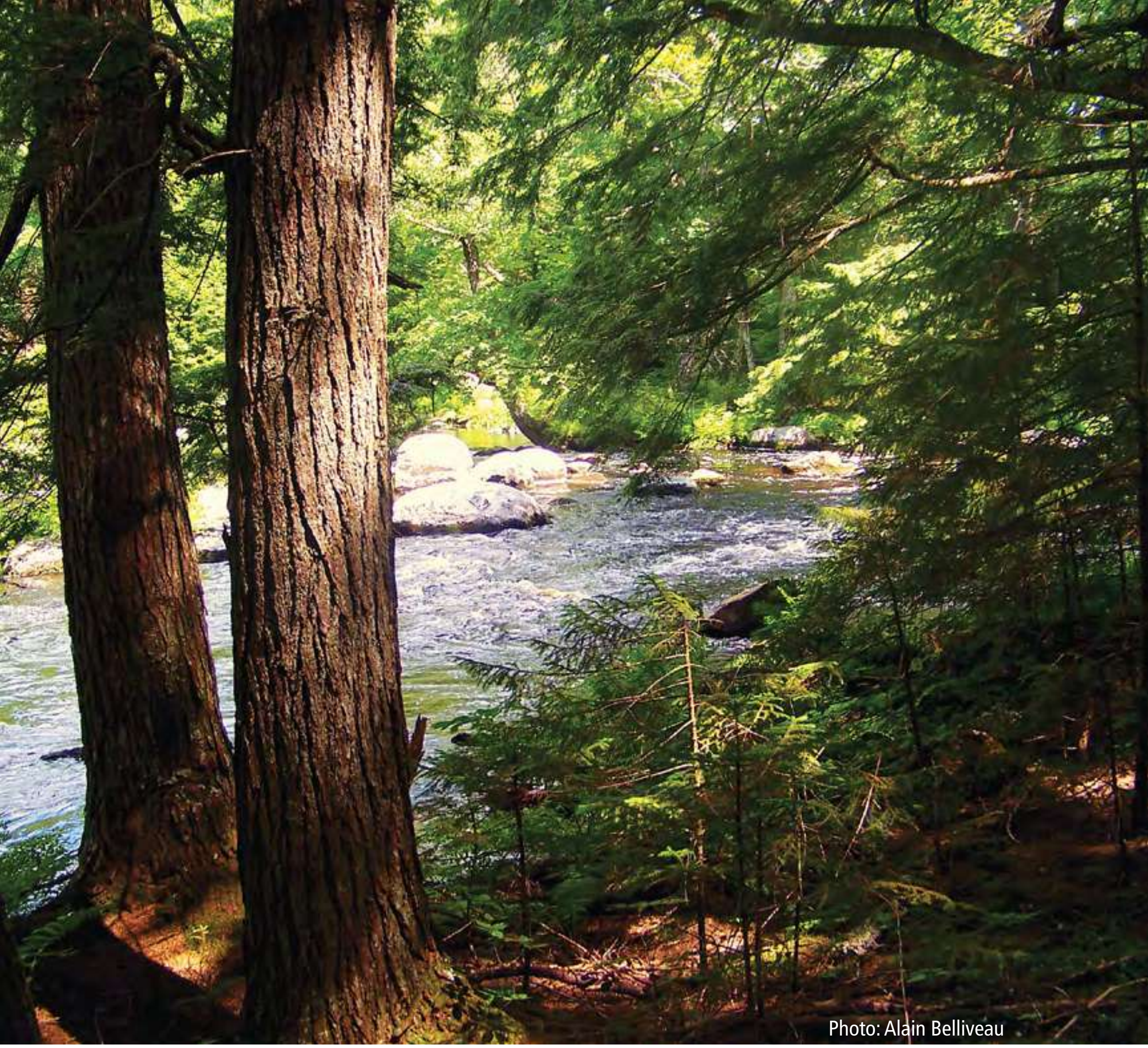

Photo: Alain Belliveau

The New England–Acadian forest region is home to a rich array of biodiversity, yet past and current land-use practices present challenges to conserving this diversity across the region. Many of the long-lived forest communities that once blanketed the landscape are in decline, including the wildlife species that depend on them. However, with the creative use of silviculture (and a little patience), these forests can be restored, along with the benefits they provide to both people and wildlife.

New England–Acadian Forest Restoration provides woodlot owners, land trusts, and protected area managers with a comprehensive how-to guide to restoring old forest conditions on degraded and converted lands. Developed with a team of experts from both the United States and Canada, the manual draws on a robust mix of scientific literature and professional experience. No matter what your motivation—concern for the natural legacy left to future generations, a mandate to conserve wildlife, or a general desire to improve your woodlot—*New England–Acadian Forest Restoration* will equip you with the tools to effectively restore forest biodiversity.